ETM Industry: Tabletop
Defining Notions of Cooperative Operating Practices
January 10-11, 2023

Upper Class E Traffic Management (ETM)

Agenda Overview

Day 1: January 10, 2022 (9am – 1pm PDT)		
Welcome/Introductions	30 min	Connie
- Agenda		
- NASA: Moderators, Project Management		
- ETM Community Participants		
Logistics		
- Microsoft Teams overview		
Overview/Background/Goals of this Tabletop	30 min	Connie
- Objectives of Collaborative Evaluation #1 (Fall 2023)		
- Objectives of this Tabletop		
Lexicon	30 min	Connie
Road to Cooperative Operating Practices		
- Online Questionnaire- Vehicle Operations	10 min	
Break	15 min	
Round 1: Creating an Operational Plan/Intent (OP/OI)	**~2 hours**	
- Training/Familiarization	25 min	Connie
- Discussion Session	75 min	Mark
▪ Operator Develops Operation Plan		
▪ Operational Intent Generation		
▪ Information Update Rates		
▪ Operator Submits OP/OI- ETM System Response		
- Online Questionnaire	10 min	
Day 1 Wrap-Up	15 min	

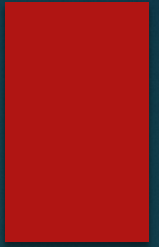| Day 2: January 11, 2022 (9am – 1pm PDT)		
Round 2: Strategic Conflict Detection	**~2 hours**	
- Welcome Back and Training/Familiarization	30 min	Connie
- Discussion	75 min	Paul
▪ OI Intersect		
▪ OI Intersect Triggers		
▪ Conflict Probability/Likelihood		
▪ Assess Parameters and Decision Points		
- Online Questionnaire	10 min	
Break	15 min	
Round 3: Cooperative Operating Practices (COPs) for Strategic Deconfliction	**~2 hours**	
- Training/Familiarization	15 min	Connie
- Discussion	70 min	Mark
▪ NASA and AIA Draft COPs		
▪ General Assumptions for COPs		
▪ Iterative Walkthrough of 3 Types of COPs		
▪ COPs Process/Agreement/Actions/Formats		
- Online Questionnaire	10 min	
Tabletop Wrap-Up	15 min	

Introductions

- The Tabletop Team
  - Name
  - Affiliation
  - Position
  - Background
- The Industry Participants
  - Name/Company
  - Position at Company
  - Vehicle Represented
  - Upper E Experience

Tabletop Logistics

- ▶ Microsoft Teams Etiquette
  - ▶ Please respect everyone's right to speak
    - ▶ Be courteous, avoid the urge to "jump in"
    - ▶ If needed, use the "Raise Hand" function
    - ▶ Use the chat to make comments, ask questions or clarify points as desired
  - ▶ Please follow the direction of the Monitor
  - ▶ Find a location that will minimize interruptions and distractions
  - ▶ Mute your microphone when not speaking
  - ▶ Please leave your <u>video on</u> during the sessions
- ▶ Online Questionnaire (Qualtrics) Access: Separate email from @qemailserver.com
- ▶ Video/Audio/Transcript Recording for Internal NASA use only
- ▶ 15-minute Break

Why ETM Tabletop?
Research and Prototype Development Walkthrough
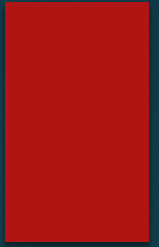
Your opinions & personal experiences help NASA to:

- ▶ Identify gaps in practice, procedures, and technology that present barriers to ETM concept
- ▶ Make recommendations for procedural and technical mitigations that facilitate ETM integration

Iterative Research Process

- ▶ Gather concerns, interest, suggestions …
- ▶ Develop concept ideas to address the potential needs/desires
- ▶ Design and model various functionalities in order to build on roles & responsibilities and procedures.
- ▶ Build prototypes to help visualize and test feasibility to evaluate and refine the concept

Tabletop Process

Description of events under discussion

Clarification Questions

Directed Research Questions

Panel Responses

ETM Swimlane Chart

Online Survey

qualtrics.XM

Tabletop Discussion:
Road to Cooperative Operating Practices

ROUND 1

ROUND 3

ROUND 2

100
Operator develops Operation Plan

140
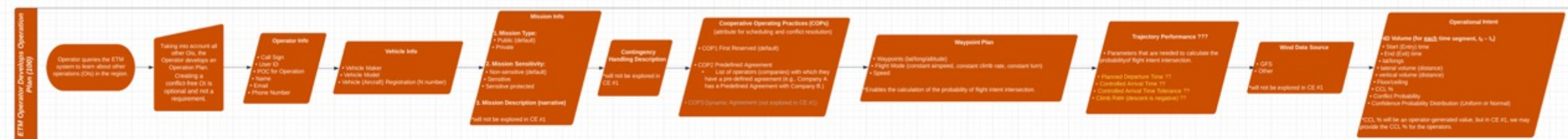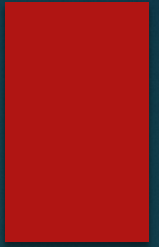Operators coordinate via COPs to address the OI intersect notification

110
Operator submits initial or an updated Operation Plan with Operational Intent (OI) to the ETM system

120
ETM system accepts/ rejects Operation Plan

130
ETM system informs of any strategic OI intersection

NO

YES

NO

YES

ETM Operator Develops Operation Plan (100)

Operator queries the ETM system to learn about other operations (OIs) in the region.

Taking into account all other OIs, the Operator develops an Operation Plan. Creating a conflict-free OI is optional and not a requirement.

Operator Info
• Call Sign
• User ID
• POC for Operation
• Name
• Email
• Phone Number

Vehicle Info
• Vehicle Maker
• Vehicle Model
• Vehicle (Aircraft) Registration (N number)

Mission Info
1. Mission Type:
• Public (default)
• Private

2. Mission Sensitivity:
• Non-sensitive (default)
• Sensitive
• Sensitive protected

3. Mission Description (narrative)

*will not be explored in CE #1

Contingency Handling Description

*will not be explored in CE #1

Cooperative Operating Practices (COPs)
(attribute for scheduling and conflict resolution)

• COP1 First Reserved (default)

• COP2 Predefined Agreement
    • List of operators (companies) with which they have a pre-defined agreement (e.g., Company A has a Predefined Agreement with Company B.)

• COP3 Dynamic Agreement (not explored in CE #1)

Waypoint Plan
• Waypoints (lat/long/altitude)
• Flight Mode (constant airspeed, constant climb rate, constant turn)
• Speed

*Enables the calculation of the probability of flight intent intersection.

Trajectory Performance ???
• Parameters that are needed to calculate the probability of flight intent intersection.

• Planned Departure Time ??
• Controlled Arrival Time ??
• Controlled Arrival Time Tolerance ??
• Climb Rate (descent is negative) ??

Wind Data Source
• GFS
• Other

*will not be explored in CE #1

Operational Intent
4D Volume (for each time segment, t₀ - t₁)
• Start (Entry) time
• End (Exit) time
• lat/long:
• lateral volume (distance)
• vertical volume (distance)
• Floor/ceiling
• CCL %
• Conflict Probability
• Confidence Probability Distribution (Uniform or Normal)

CCL % will be an operator generated value, but in CE #1, we may provide the CCL % for the operators.

ETM Operator 1 Company A	ESS	ETM Operator 2 Company B

Round 1

Operator 1 submits an Operation Plan. The ESS detects no conflicts with other OIs.

Goal: Collaborative Evaluation #1 (CE-1)
Fall 2023~

▶ NASA Functionality Developed for Cooperative Operations

    ▶ Operational Intent (OI) Generation Service

    ▶ Containment Confidence Level (CCL) of OI Volumes

    ▶ OI Intersection- Strategic Conflict Detection and Assessment

    ▶ OI Conflict Probability

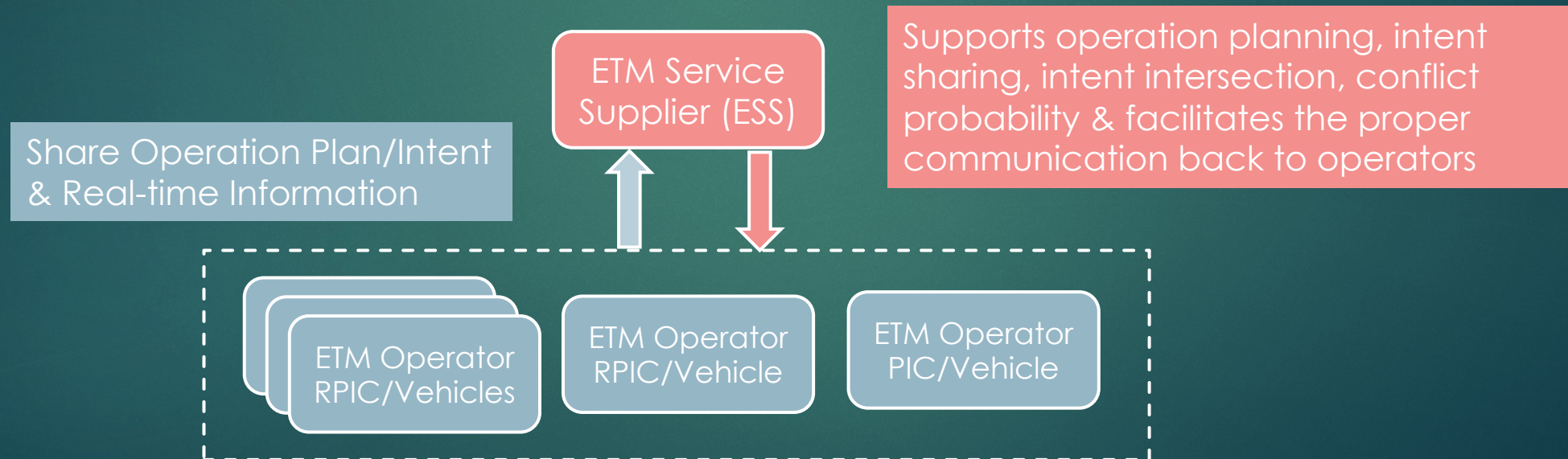▶ Initial set of Cooperative Operating Practices (COPs) for Strategic Deconfliction

Objective~

Invite ETM community partners for evaluation and exploration of a prototype NASA research ETM system

ETM Tabletop Overview:
Generalized ETM System

Cooperative Operations

▶ Goal to operate "safely" and "cooperatively" within Upper-Class E

▶ Emphasized through _intent sharing_ and supported by a _service-oriented architecture_

Supports operation planning, intent sharing, intent intersection, conflict probability & facilitates the proper communication back to operators

ETM Service Supplier (ESS)

Share Operation Plan/Intent & Real-time Information

ETM Operator RPIC/Vehicles

ETM Operator RPIC/Vehicle

ETM Operator PIC/Vehicle

Industry Partner Role in Tabletop

▶ Honest opinions guided by previous ETM meetings/workshops/papers/experiences are strongly encouraged

▶ Please do not hesitate to express conflicting points of view to help us mold this altogether

▶ Represent Vehicle Type

▶ Utilize online questionnaires for further open dialogue opportunities

ETM Cooperative Operating Practices
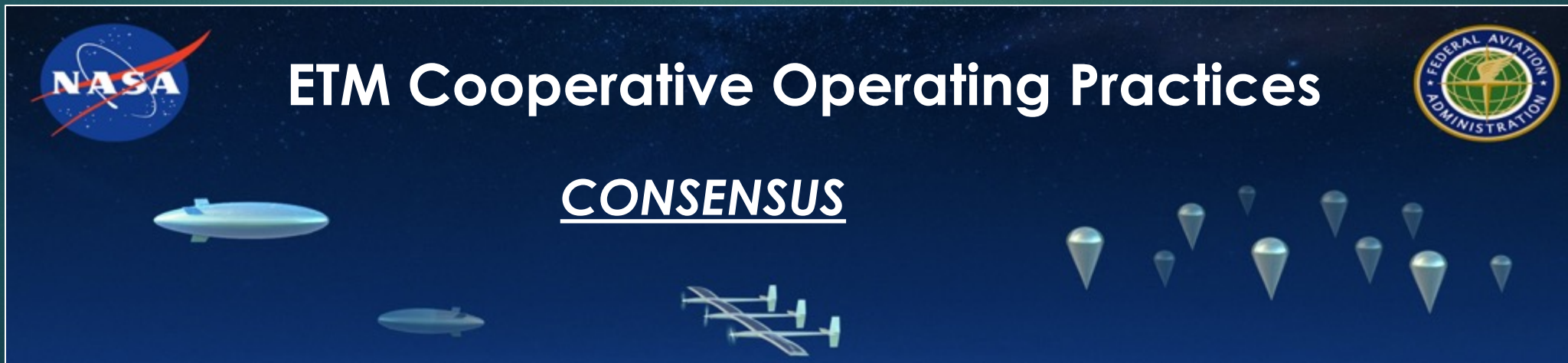
CONSENSUS

Tabletop Objectives

▶ Our goal is to *leverage your expertise* and *come to consensus* on various aspects of Upper E cooperative operations

▶ Assume *nominal* conditions within ETM when discussing each event

▶ After an introduction to each of the rounds, we will utilize an ETM 'swim lane' chart to follow the *system process* for each round

▶ Then, a guided discussion with some directed questions

▶ Followed by online survey for any further thoughts and specifics for each concept

Industry Driven Research Questions

- How to generate and model operational intent volumes?

- What is proper duration of OI 'rolling window'?

- Explore probabilistic range of confidence in OI Volumes?

- What are the temporal and spatial boundaries of cooperative separation (Strategic Conflict Detection and De-confliction)

- What are the key likelihood/probability de-confliction parameters to establish COPs

- Explore 'service suppliers' for inter-operator communication, conflict monitoring and resolution negotiation

- Address/identify equity and fairness principles

- Validate collaborative operation/community-based rules via simulation platforms

Training Objectives

Upon completion of the training, all participants should:

► Be familiar with the path to COPs for strategic deconfliction focusing on 3 main 'rounds'

   ► Round 1: Submit Operation Plan with Operational Intent (OI)

      ► OI Characteristics and NASA research on OI Generation options/services

      ► NASA research on OI Containment Confidence Levels (CCL)

   ► Round 2: Strategic Conflict Detection: Intersecting OI

      ► Define Decision Point (wait or take-action)

      ► Impact of the OI size, update cycle and CCL

      ► NASA research on Conflict Probability (CP) and corresponding threshold criteria

   ► Round 3: NASA COPs for Strategic De-confliction

      ► Pre-defined Agreements

      ► Baseline standard resolutions

ETM Tabletop Lexicon
Day 1~

- *Cooperative Operating Practices (COPs):* set of pre-agreed operating rules and procedures to maintain separation while promoting safety, cooperatively, fairly and equitably

- *Operations Plan (OP):* comprehensive operator, vehicle and mission information-including operational intent, that the operator submits as required to enable the cooperative ETM system

- *Operational Intent (OI):* spatial and temporal elements of a planned operation that can be used to gain situation awareness of nearby operations, support demand/capacity balancing, identify potential conflicts etc...

- *Operational Intent Volumes:* resulting four-dimensional (4D) block of airspace , shared in a series of segments which represent full flight intent prediction over the next 'x'- duration (time horizon)

- *Operational Intent Update Rate*: regular and frequent updates to OI is important to ensure confidence in your OI size and duration.

- *Rolling Window*: term used for a number of OI volume segments updated at a specified rate

- *Containment Confidence Level (CCL):* estimated value of how confident that you will actively stay in your given volume
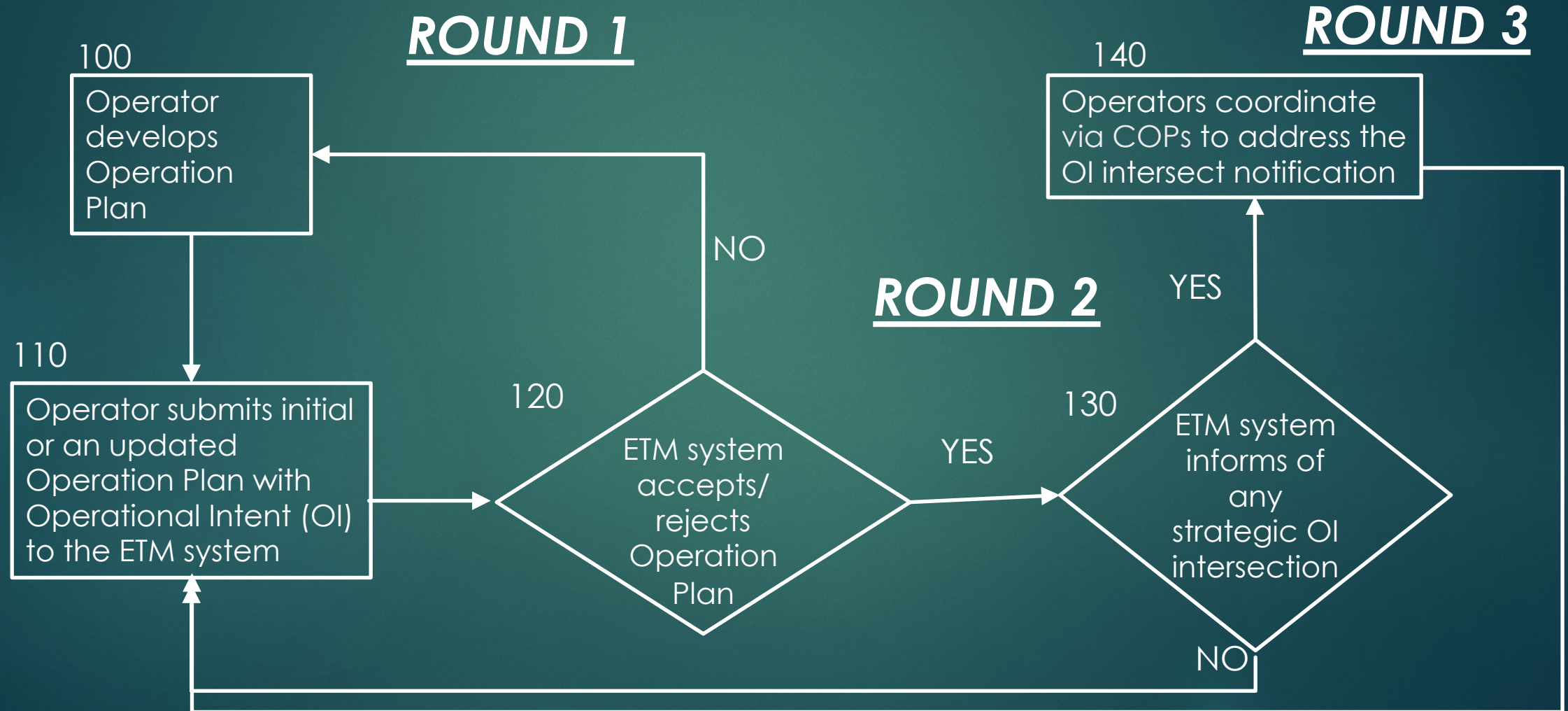
ETM Tabletop Lexicon (cont.)
Day 2~

- *Strategic Conflict 'Detection':* Two or more OI volumes intersect in space and time

- *Strategic 'Deconfliction'*: methods to strategically solve OI intersection

- Conflict Probability: likelihood of vehicles getting close within a defined separation standard or Likelihood of vehicle conflict based on predicted vehicle paths, calculated independently from OI Intersection calculations

- *Conflict Probability Alert Setting Thresholds*: The pre-defined parameters to notify the operators of the estimated proximity of another vehicle

- *Separation Envelope*: distance between predicted vehicle locations that would trigger the alert

- *Flight Information Update Rate*: regular and frequent updates to active flight telemetry data are important for the OI Intersect and/or conflict probability calculations in the ETM system

- *Assess the Strategic Conflict*: given OI volume intersect and/or conflict probability alert information, the operator will weigh the options

- *Decision Point*: the collaborative resolution time allowed when considering the assessed information and whether to 'wait-and-see' or 'take-action' (enact COPs)

- *Cooperative Operating Practices (COPs):* **s**et of pre-agreed operating rules and procedures to maintain separation while promoting safety, cooperatively, fairly and equitably
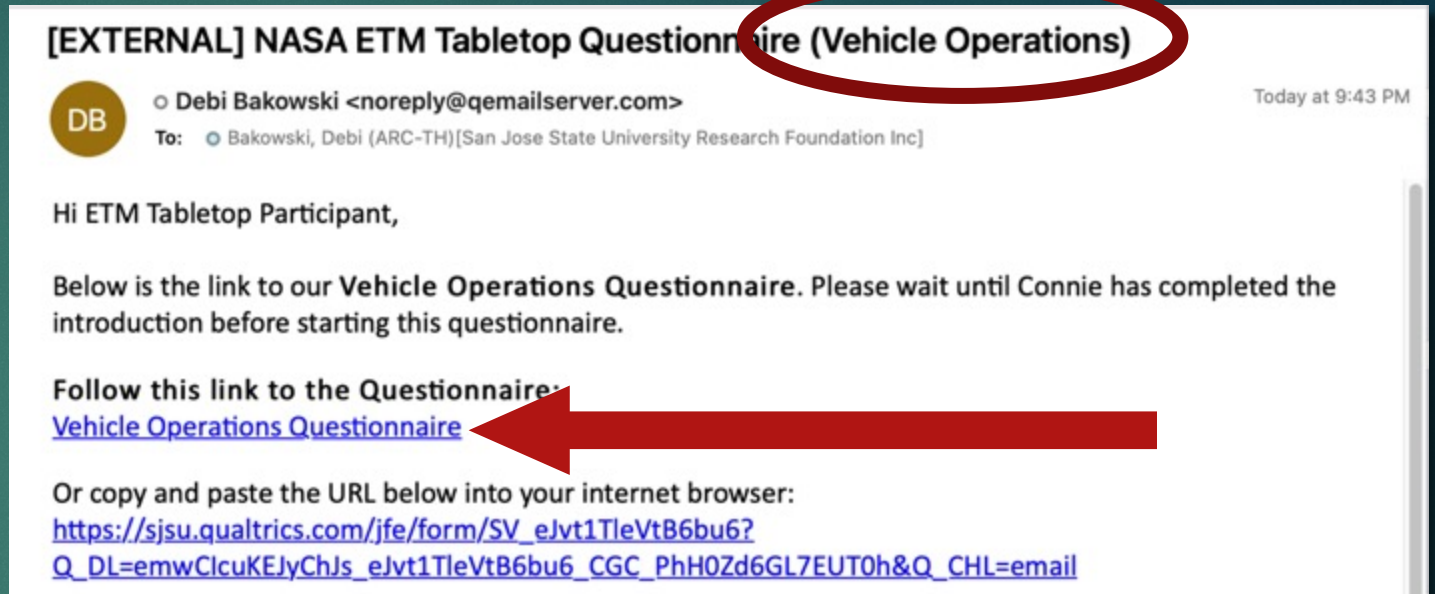
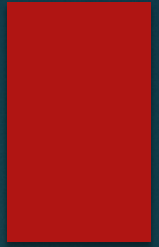# Tabletop Discussion:
Road to Cooperative Operating Practices

ROUND 1

ROUND 3

ROUND 2

100
Operator develops Operation Plan

140
Operators coordinate via COPs to address the OI intersect notification

110
Operator submits initial or an updated Operation Plan with Operational Intent (OI) to the ETM system

120
ETM system accepts/ rejects Operation Plan

NO

130
ETM system informs of any strategic OI intersection

YES

YES

NO

Vehicle Operations Questionnaire

- Access through email link.

- Answer these questions with your company's vehicle in mind.

[EXTERNAL] NASA ETM Tabletop Questionnaire (Vehicle Operations)

DB Debi Bakowski <noreply@qemailserver.com>   Today at 9:43 PM
To: Bakowski, Debi (ARC-TH)[San Jose State University Research Foundation Inc]

Hi ETM Tabletop Participant,

Below is the link to our **Vehicle Operations Questionnaire**. Please wait until Connie has completed the introduction before starting this questionnaire.

Follow this link to the Questionnaire:
Vehicle Operations Questionnaire

Or copy and paste the URL below into your internet browser:
https://sjsu.qualtrics.com/jfe/form/SV_eJvt1TleVtB6bu6?
Q_DL=emwCIcuKEJyChJs_eJvt1TleVtB6bu6_CGC_PhH0Zd6GL7EUT0h&Q_CHL=email

Questions Prior to Training for Round 1

15 Minute Break

Day 1 / Round 1: Agenda Overview

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Overview/Background/Goals of this Tabletop - Objectives of Collaborative Evaluation #1 (Fall 2023) - Objectives of this Tabletop	30 min	Connie
Lexicon Road to Cooperative Operating Practices	30 min	Connie
- Online Questionnaire- Vehicle Operations	10 min	
Break	15 min	
Round 1: Creating an Operational Plan/Intent (OP/OI)	**~2 hours**	
- Training/Familiarization	25 min	Connie

-    Discussion Session
  ▪ Operator Develops Operation Plan
  ▪ Operational Intent Generation
  ▪ Information Update Rates
  ▪ Operator Submits OP/OI- ETM System Response
	75 min	Mark

- Online Questionnaire	10 min	
Day 1 Wrap-Up	15 min	

Round 1 Training Agenda

▶ **<u>100</u>** Operator Develops Operation Plan

  ▶ Cover Expected OP Parameters

  ▶ Generation of OI Volumes

  ▶ Confidence Containment Level

▶ **<u>110</u>** Operator submits initial or an *updated Operation Plan* with Operational Intent (OI) to the ETM system

  ▶ Flight Information Update Rate

▶ **<u>120</u>** ETM system 'accepts' or 'rejects' the Operation Plan

  ▶ System Responses

100

Operator develops Operation Plan

140

Operators coordinate via COPs to address the OI intersect notification

110

Operator submits initial or an updated Operation Plan with Operational Intent (OI) to the ETM system

120 ETM system accepts/ rejects Operation Plan

NO

YES

130 ETM system informs of any OI intersection

YES

NO
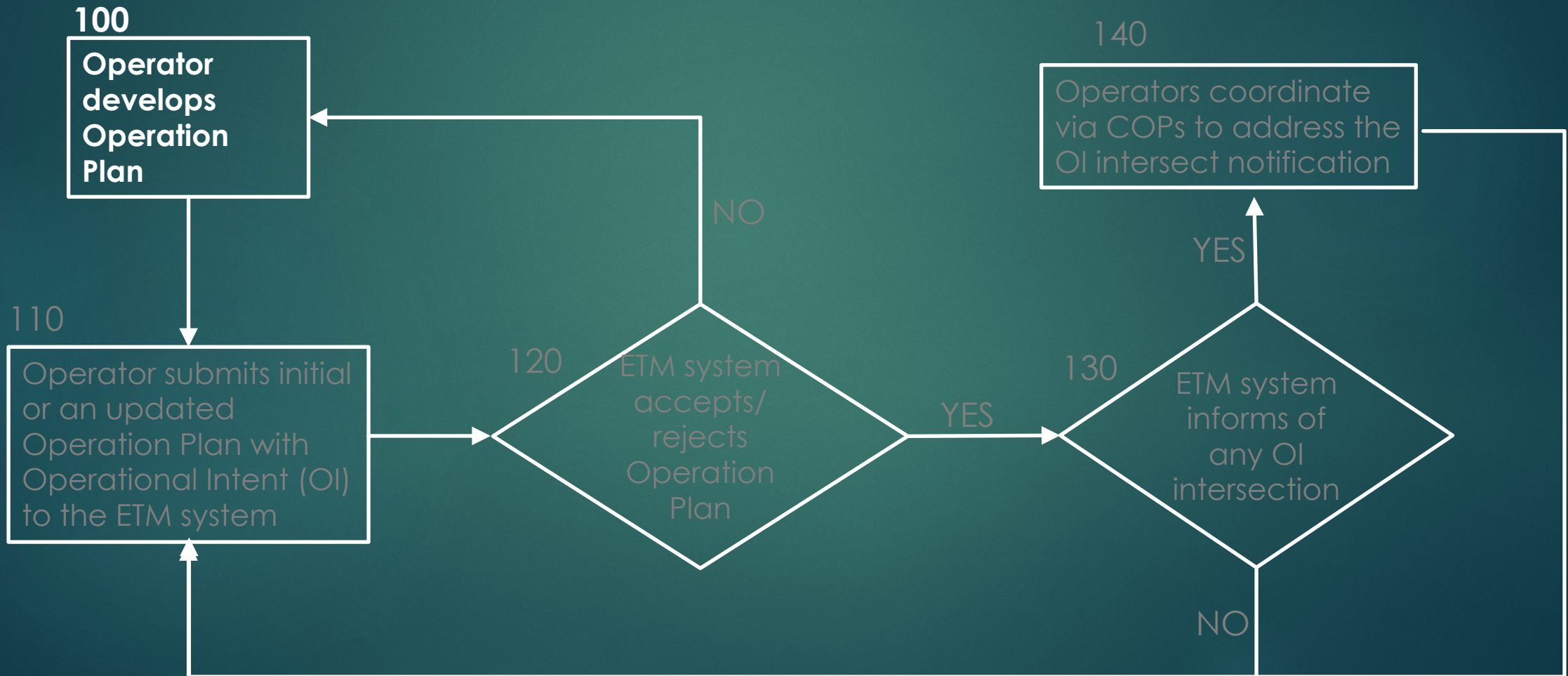
Operation Plan (OP) Developed (100)
OP Parameters Round 1of Swimlane Chart

- Operator Information
- Vehicle Information
- Mission Information
- Contingency Handling Information
- 4DT Waypoint Plan /Trajectory Performance
- Wind Data Source
- **Operational Intent (OI)**
- Cooperative Operating Practices (COPs)

Cooperative Operating Practices (COPs)
(for Strategic Deconfliction)

- COP First Reserved

- COP Predefined Agreement
  - List of operators (companies) with which they have a pre-defined agreement (e.g., Company A has a Predefined Agreement with Company B.)

- COP Dynamic Ad-hoc Agreement (not explored in CE #1)
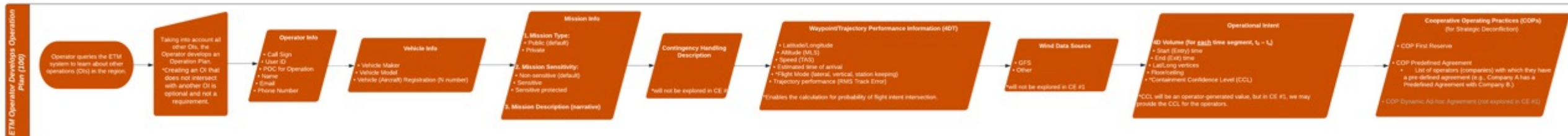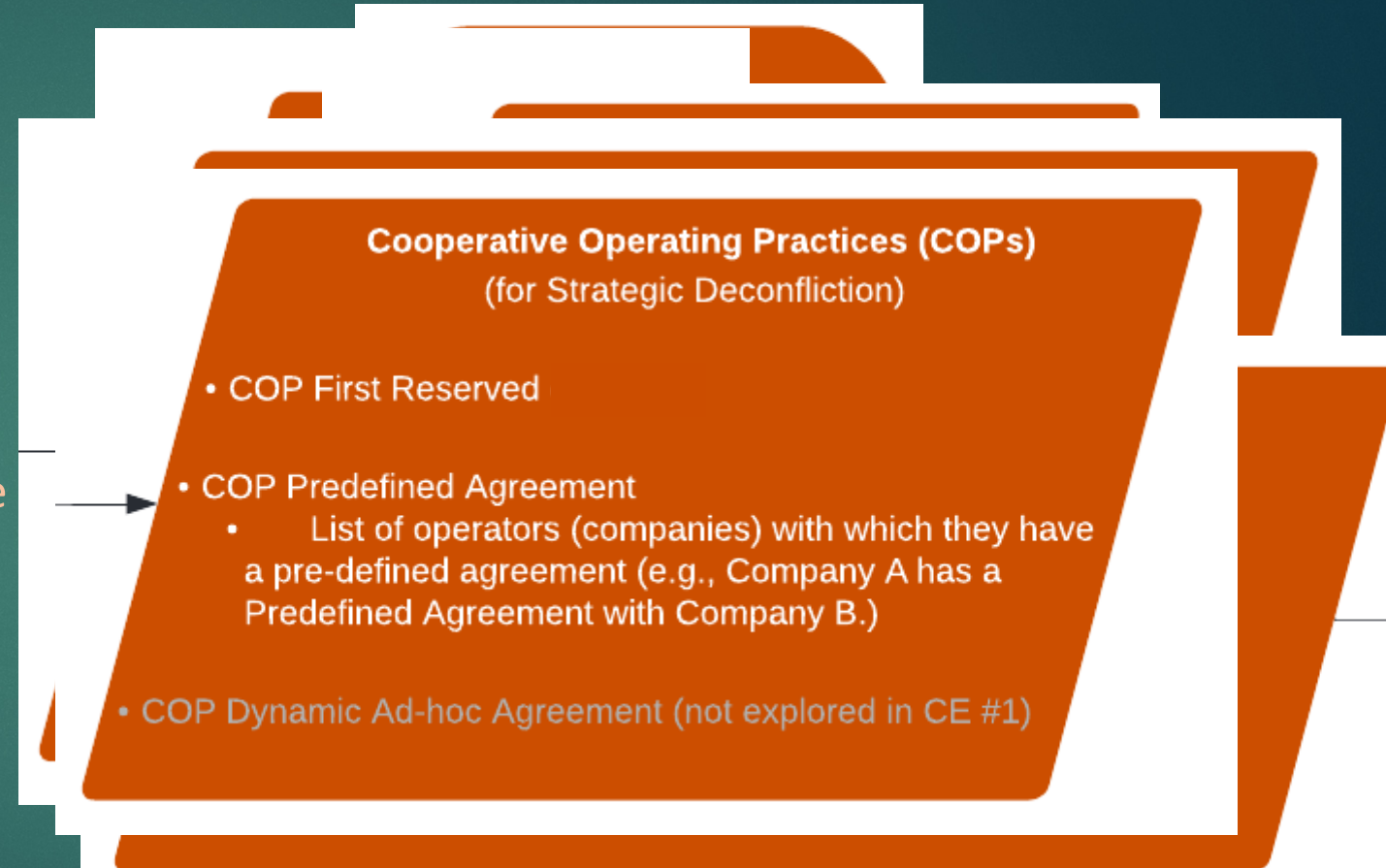
Operational Intent (OI) (100) Generation of OI Volumes

▶ _Operational Intent (OI):_ spatial and temporal elements of a planned operation that can be used to gain situation awareness of nearby operations, support demand/capacity balancing, identify conflicts etc...

▶ _Operational Intent Volumes:_ resulting four-dimensional (4D) block of airspace , shared in a series of segments which represent full flight intent prediction over the next n-min/hours

   ▶ Spatial-intended estimated trajectory

   ▶ Temporal-duration of estimated trajectory

   ▶ The volume segments could overlay each other due to uncertainties

   ▶ OI may be updated at a specified update rate using a "_rolling-window_" approach.

   ▶ _Confidence Containment Level (CCL):_ estimated value of how confident that you will actively stay in your given volume

OI Generation as a Service

▶ Operation Intent can be self-provisioned or contracted via a third-party service

▶ Required Parameters for OI 4D Volume for each segment

  ▶ Spatial-intended estimated trajectory of segment

    ▶ Lateral- lat/long polygonal set of vertices +/- buffer for uncertainties indicating where the vehicle is expected to be for the given time parameter

    ▶ Vertical- floor/ceiling +/- altitude buffer for uncertainties or maneuverability that vehicle would be expected to maintain for the given time parameter

  ▶ Temporal-duration of estimated trajectory of segment

    ▶ Duration- time of expected entry and exit (with applicable buffers) based on duration due to performance/operating characteristics and uncertainties

OI 4D Volume Segment

Vertical

Duration

Lateral
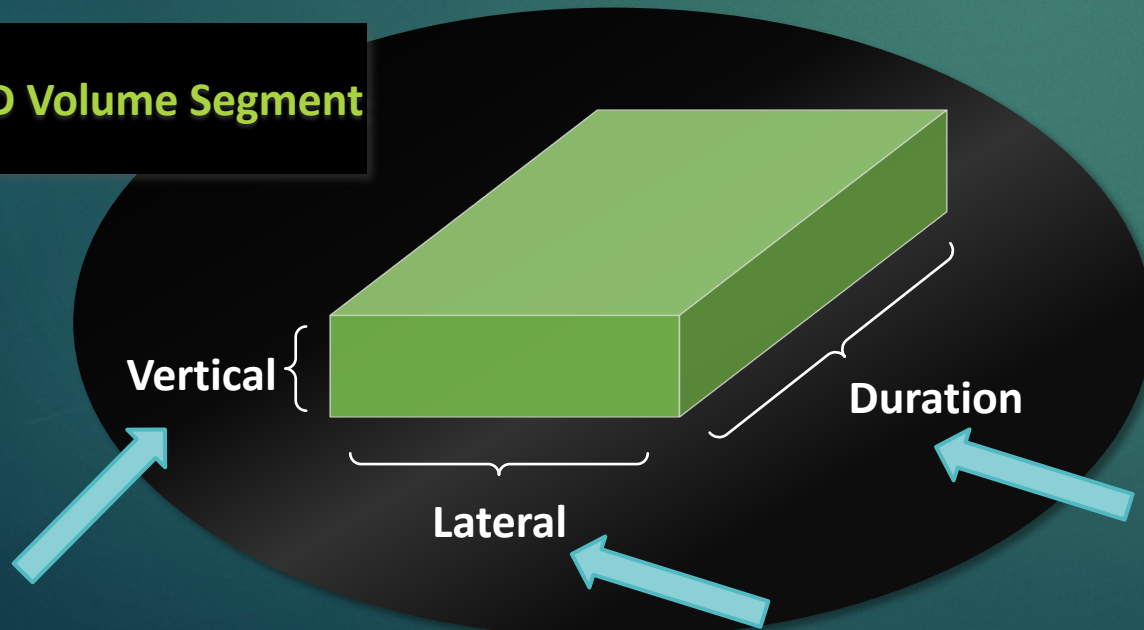
Operational Intent

4D Volume (for <u>each</u> time segment, $t_0 - t_x$)
• Start (Entry) time
• End (Exit) time
• Lat/Long vertices
• Floor/ceiling
• *Containment Confidence Level (CCL)

*CCL will be an operator-generated value, but in CE #1, we may provide the CCL for the operators.
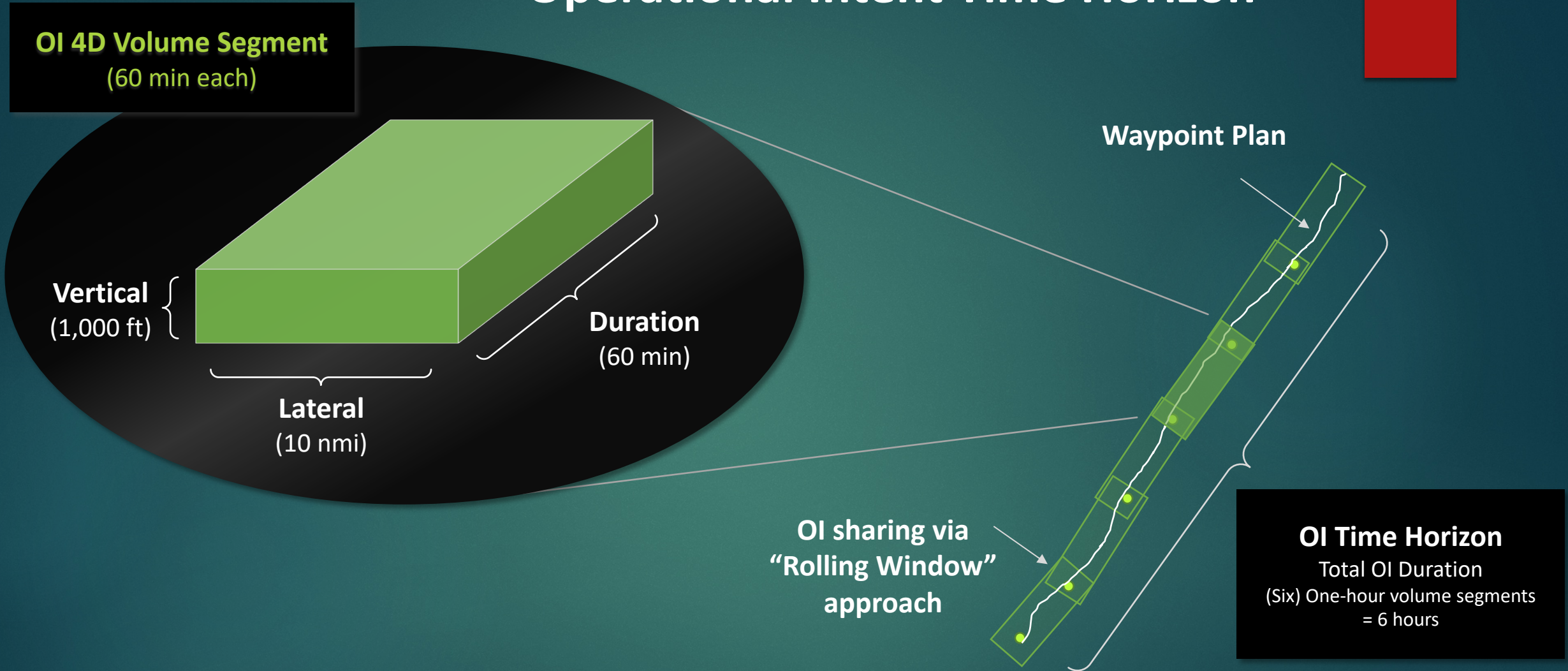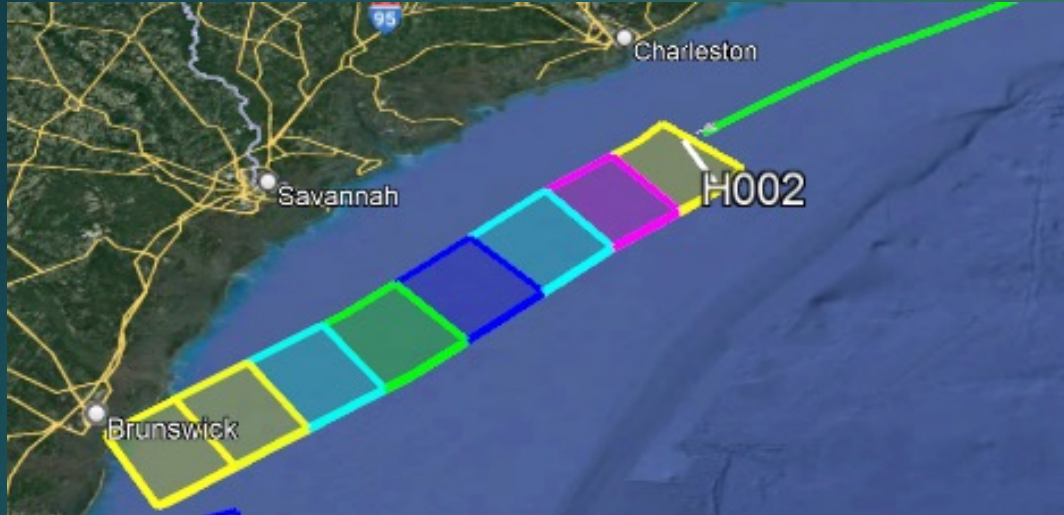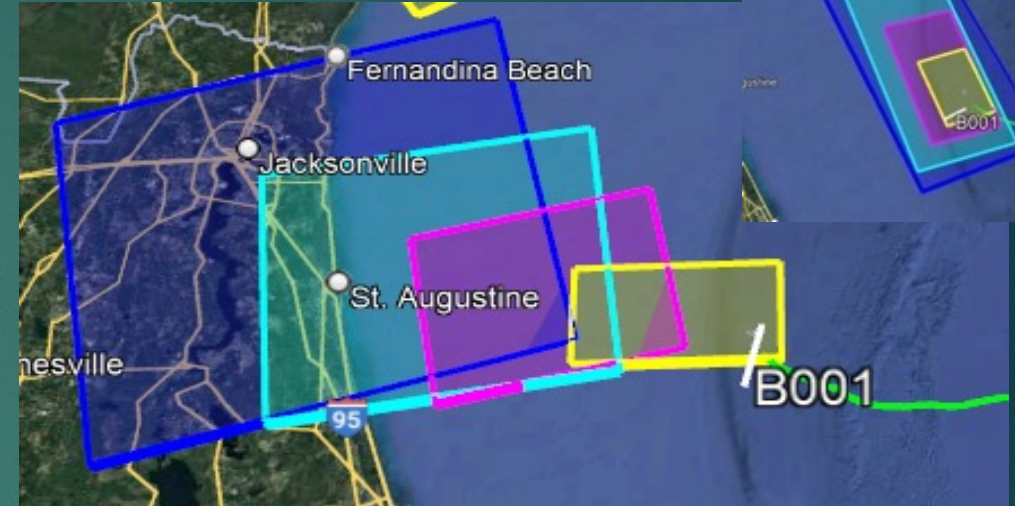
Operation Plan (100)
Examples of Operational Intent (OI) Volumes
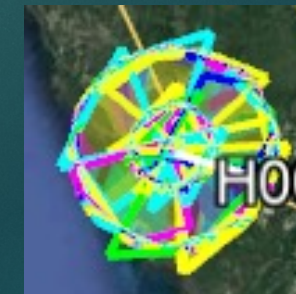
OI of a slow-speed vehicle with some maneuverability

OI of a vehicle with low maneuverability
*Volume segments could overlay each other due to uncertainties
*OI may need a specified update rate using a "*rolling-window*" approach."

OI of a high-speed vehicle with high maneuverability

What to do with holding or loitering patterns?

Operation Plan (100)
Examples of Operational Intent (OI) Volumes

- Based on Waypoint Plan

- Trajectory Performance Information

- Common Wind Data Source: NE at 20knts
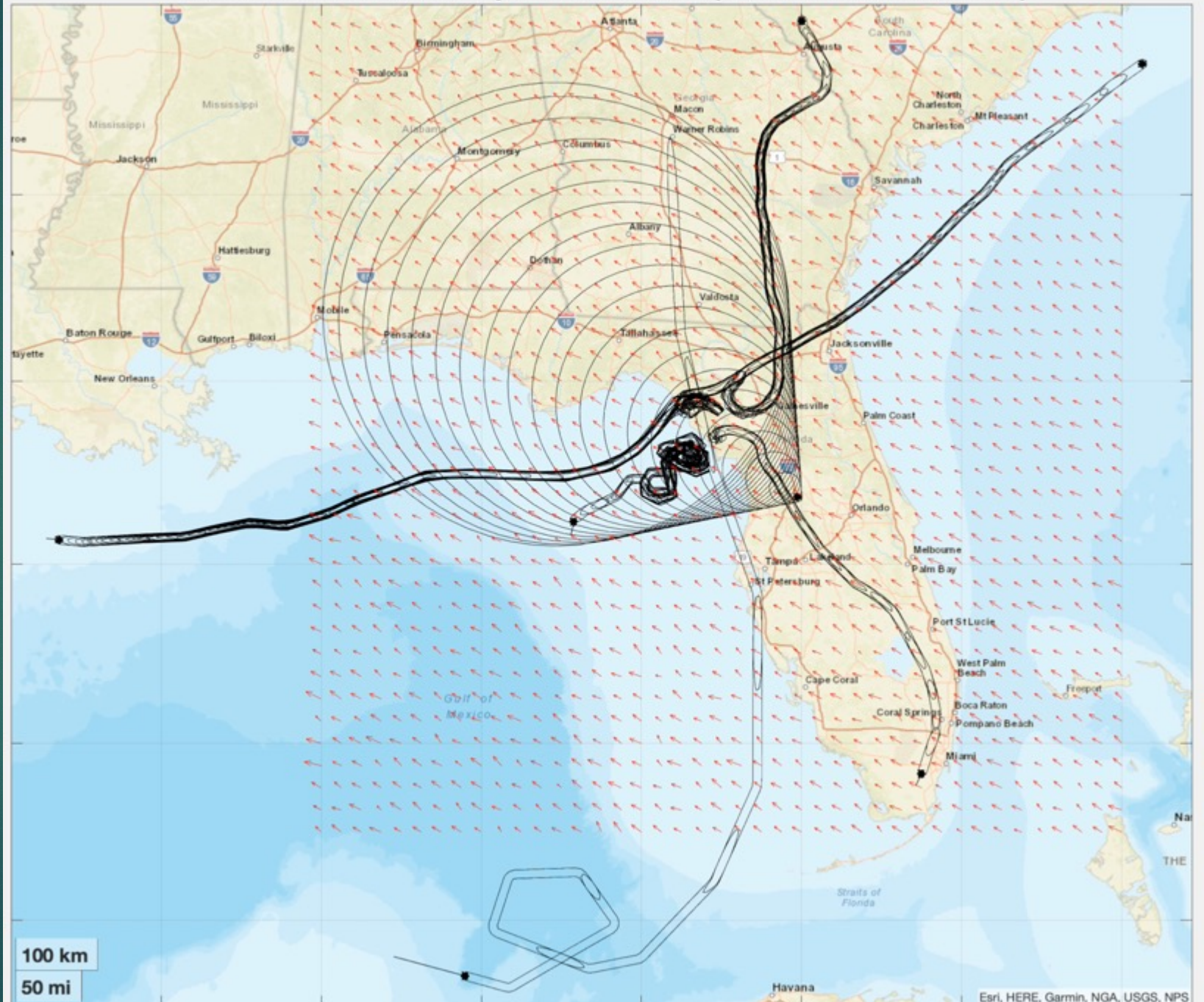
- 60 Minute OI duration

- 10 Min update rate

60 min OI
10 min update rate

Airship, Slow Hale and Global Hawk

60 min OI
10 min update rate

30 min OI
10 min update rate

10 min OI
10 min update rate

- Based on Waypoint Plan
- Trajectory Performance Information
- Common Wind Data Source: WNW at 20knts
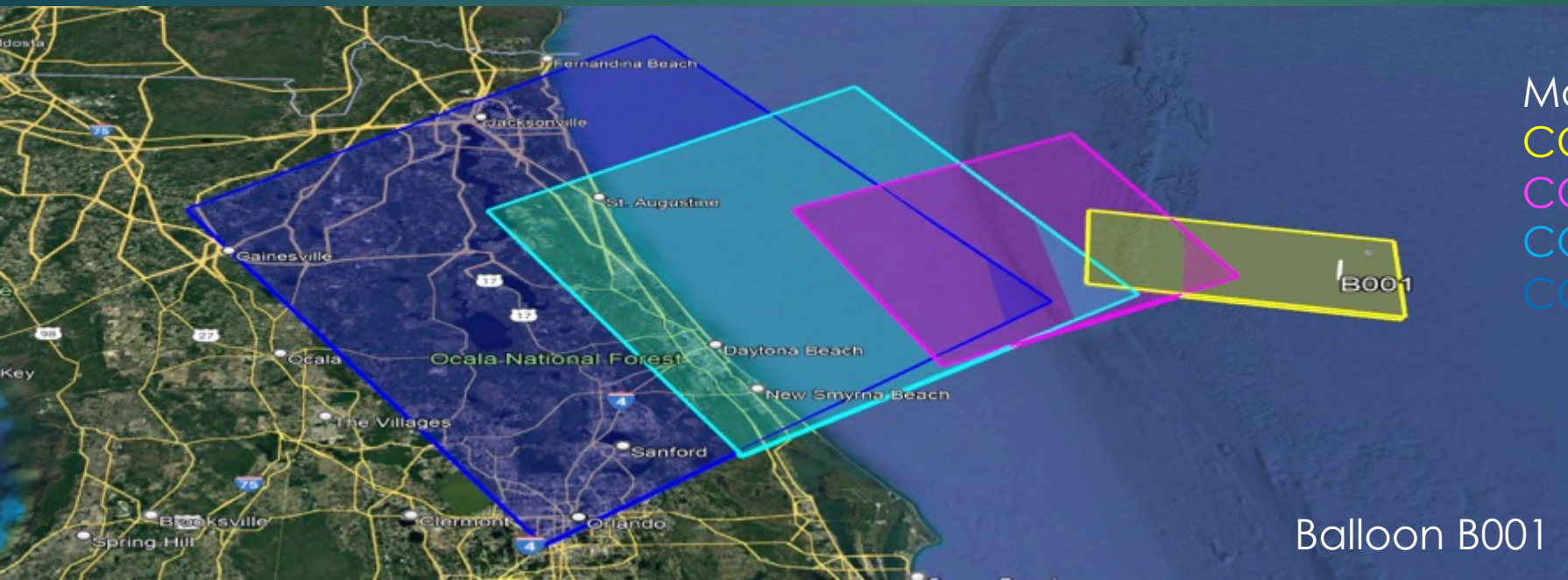- 30 Minute OI duration
- 10 Min update rate
- 10-Hour Time Horizon
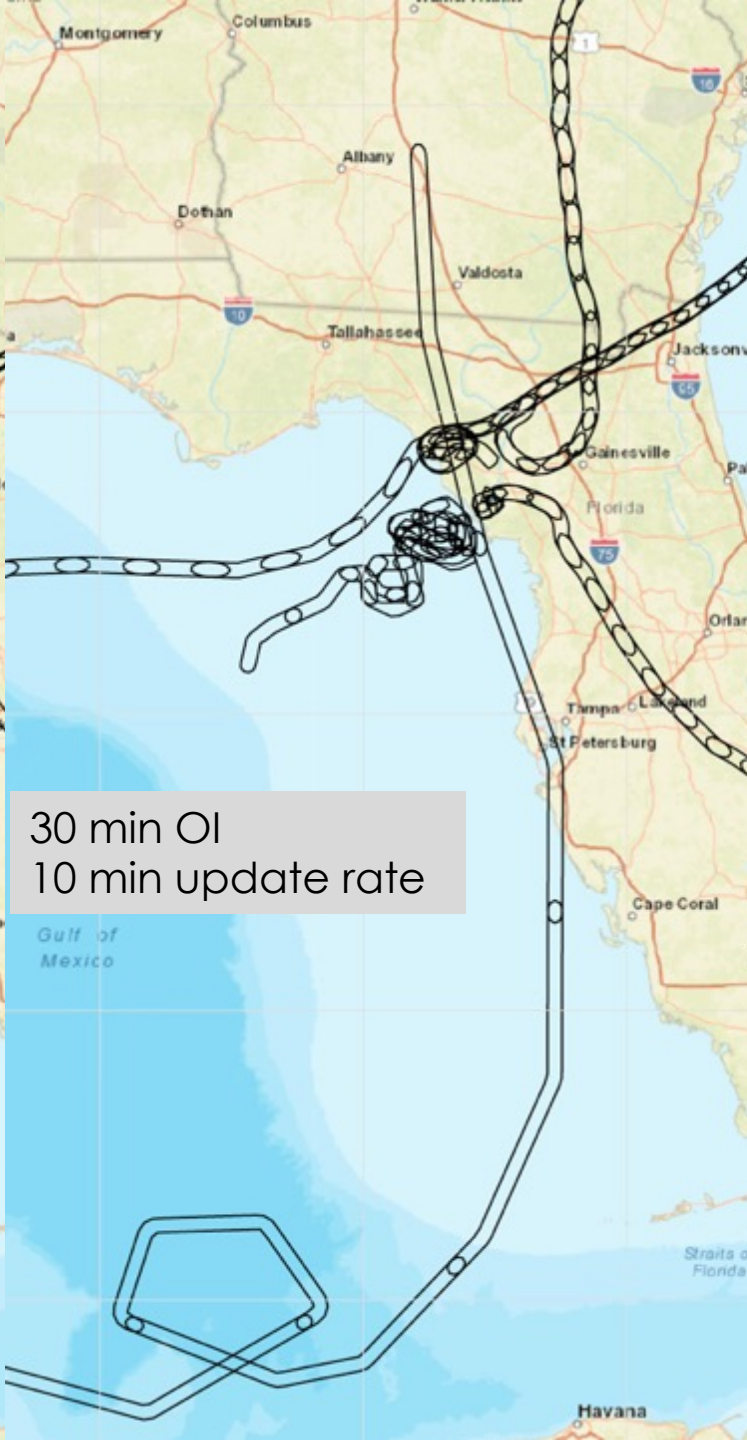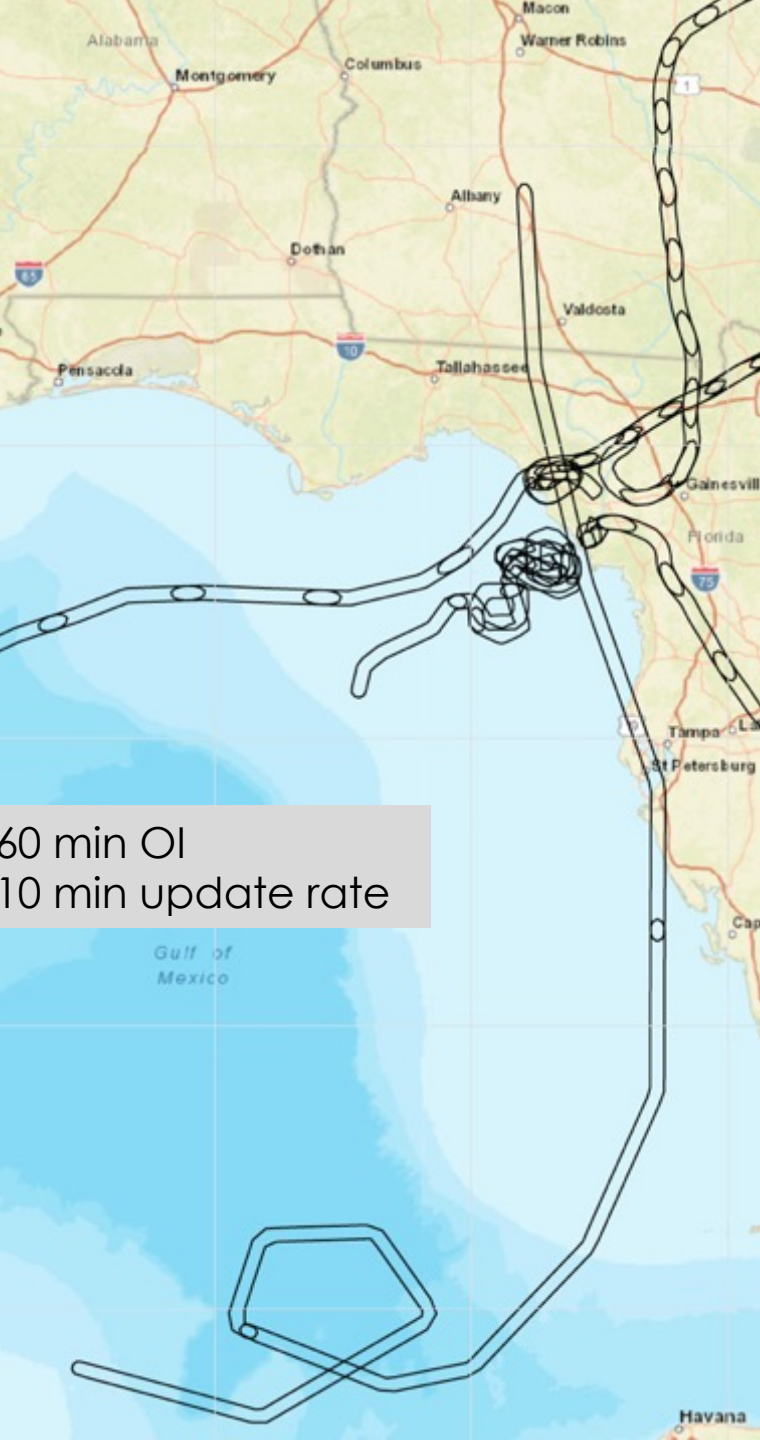
Current Time: 00:10:00 Operational Intent (Intent size = 30 minutes)

OI Containment Confidence Level (CCL)

Max Volume size 60nm-1 hour
CCL 0-60 min	100%
CCL 60-120	94%
CCL 120-180	90%
CCL 180-240	55%
CCL 240-300	36%
CCL 300-360	25%

Max Volume size 120nm-1 hour
CCL 0-60 min	100%
CCL 60-120	100%
CCL 120-180	99%
CCL 180-240	99%

Balloon B001

CCL 100% for 20nm

6 hours prediction time horizon

Update rate = 60 minutes
OI duration = 60 minutes
OI size restriction = 60 nm

6 hours prediction time horizon

Update rate = 30 minutes
OI duration = 30 minutes
OI size restriction = 60 nm

6 hours prediction time horizon

Update rate = 10 minutes
OI duration = 10 minutes
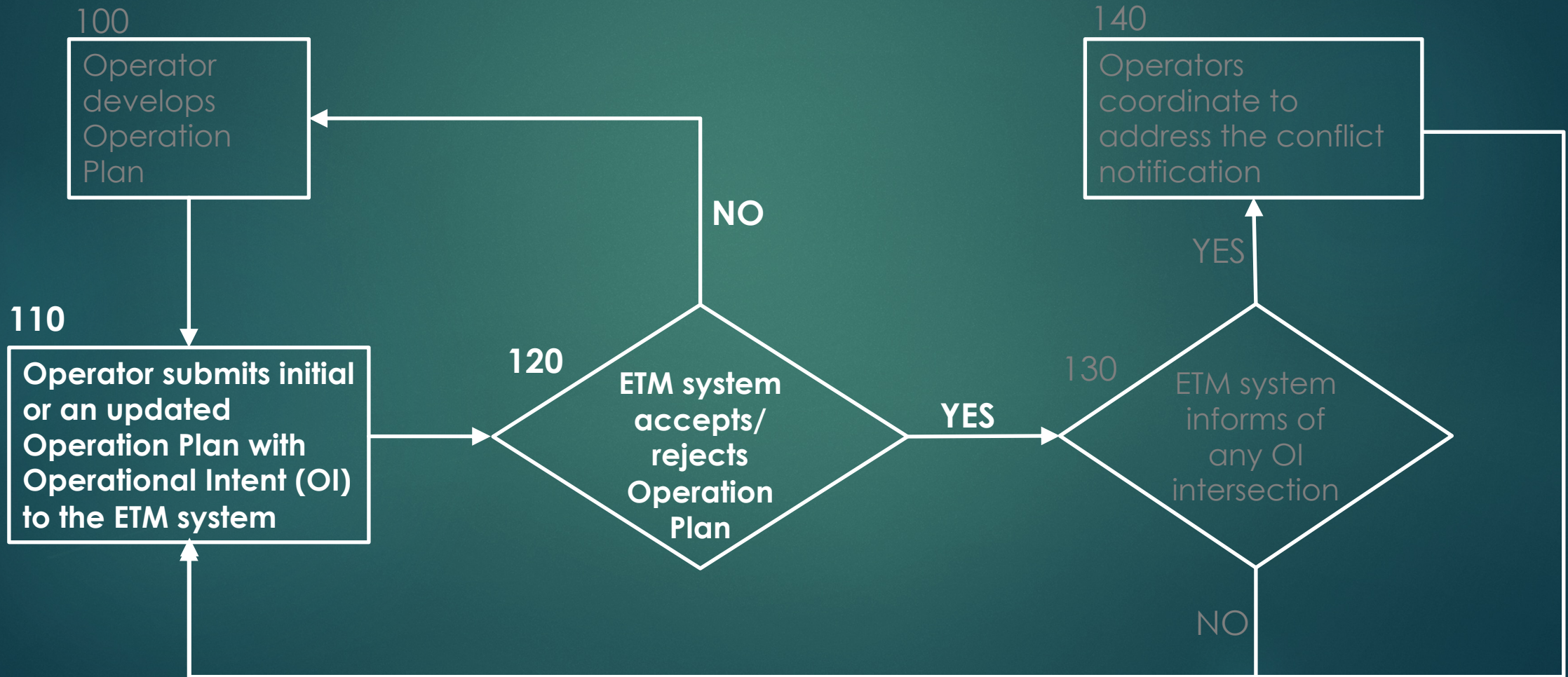OI size restriction = 60 nm
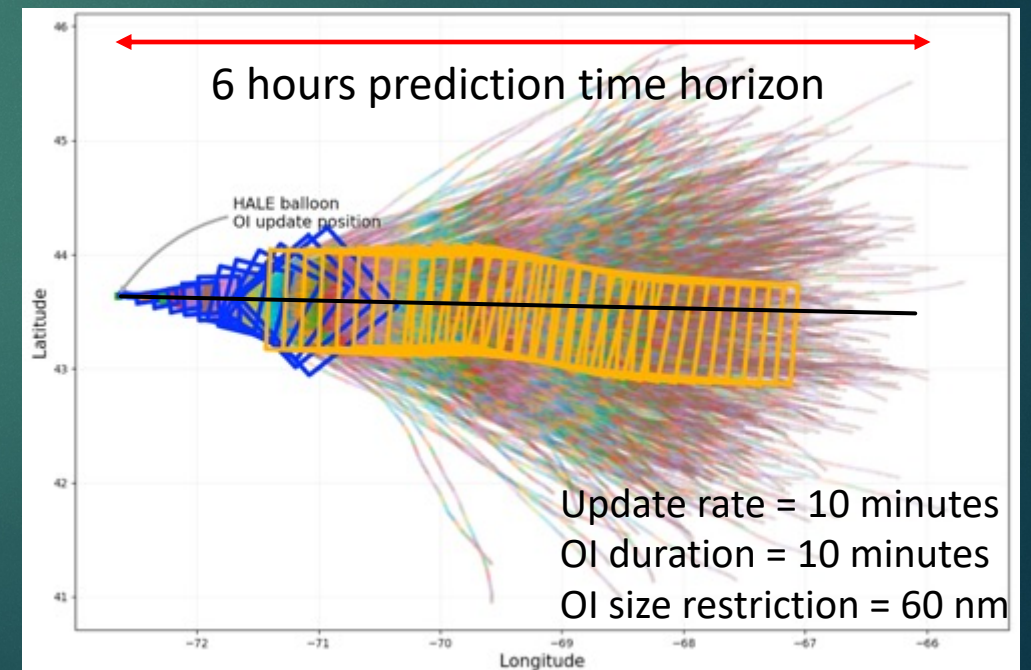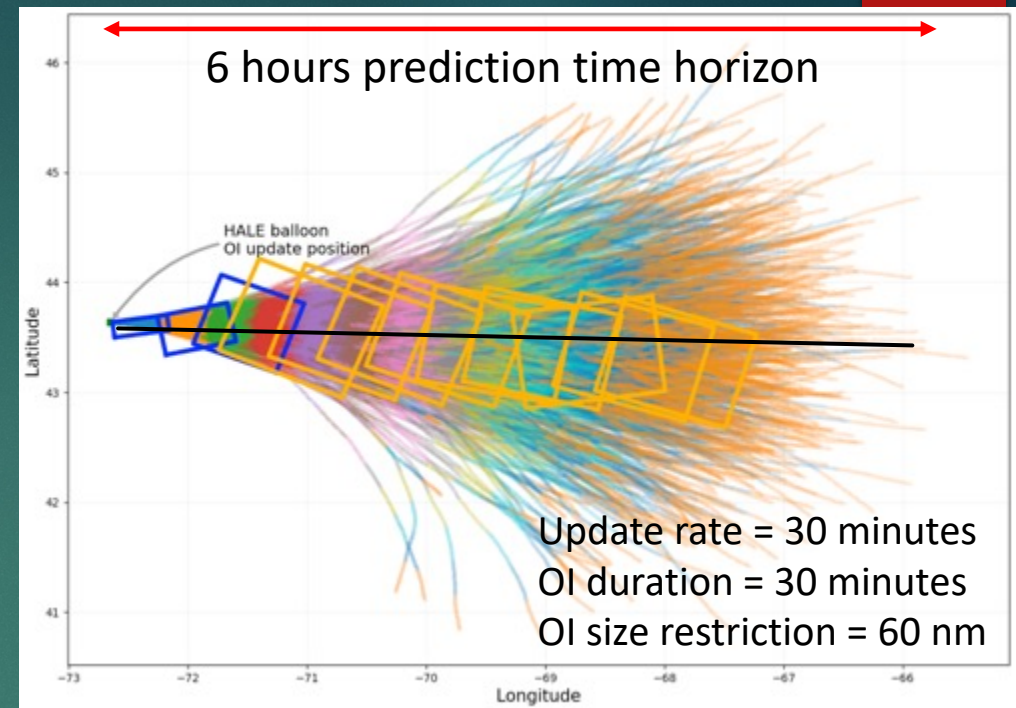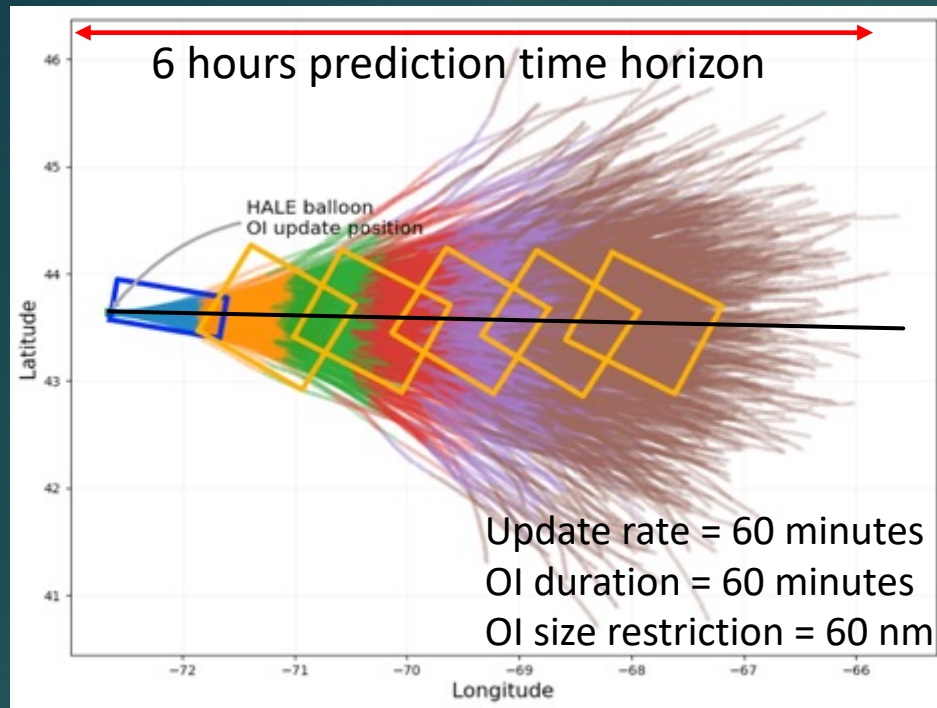
OI Volume Update Rate

▶ OI Segment Update Rate

▶ OI Segment Duration

▶ OI Segment Size Restriction

▶ Total OI Time Horizon

blue greater than 95% CCL - yellow is less than 95% CCL

100
Operator develops Operation Plan

140
Operators coordinate to address the conflict notification

110
Operator submits initial or an updated Operation Plan with Operational Intent (OI) to the ETM system

120
ETM system accepts/ rejects Operation Plan

NO

YES

130
ETM system informs of any OI intersection

YES

NO

Operation Plan Submission
ETM System (ESS) Response (110/120)

▶ ESS Responses to Operator

- ▶ Proposed: This operation is not yet ACCEPTED. It may be awaiting information, or for some other reason it is not yet able to be declared ACCEPTED.

- ▶ Rejected: something in plan is not valid – wrong format, outside defined limits etc...

- ▶ Accepted (no OI conflict detected): indicates that the OI meets all requirements to access and operate in the ETM environment but is not yet in operation.

- ▶ Accepted with OI intersect (130 more details to come in Round 2)

- ▶ Activated

- ▶ Conforming

- ▶ Nonconforming
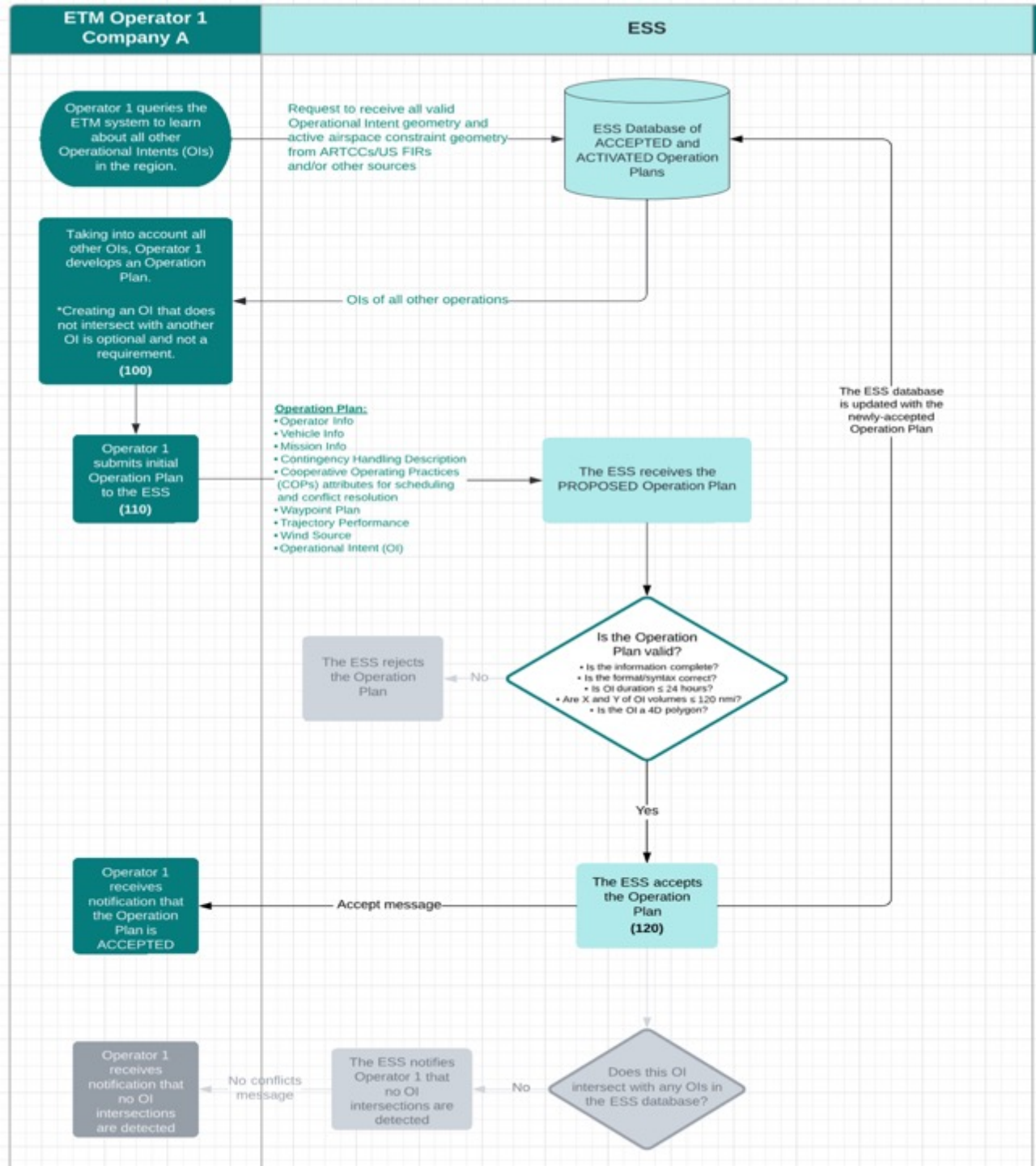
- ▶ Contingent

- ▶ Closed

Round 1

Operator 1 submits an Operation Plan. The ESS detects no intersections with other OIs.

▶ Scenario for Round 1 (100/110/120)

  ▶ Query the ETM system for other operations

  ▶ Build OP/OI

  ▶ Submit OP/OI

  ▶ Proposed to ETM System

  ▶ Accepted no Conflict

Detailed Discussion Questions Round 1
Mark Evans

Round 1: Operational Intent (OI)

Primary Focus

– Operational Intent (OI) Volume Size Characteristics

– OI Volume Requirements Standardization

– Minimum/Maximum Size of OI Volumes

Time Permitting

– Rolling Window

– OI Volumes and Containment Confidence Level (CCL) Use

Agreement on OI Characteristics

– When you generate your OI for submission, how would you determine the OI volume size?

– As a community, would you be agreeing to generate the smallest OI volumes needed for a specified pre-determined level of conformance?

– Are there any criteria – beside *vehicle performance* – that might be used for determining OI volume size?

OI 4D Volume Segment

Vertical

Duration

Lateral
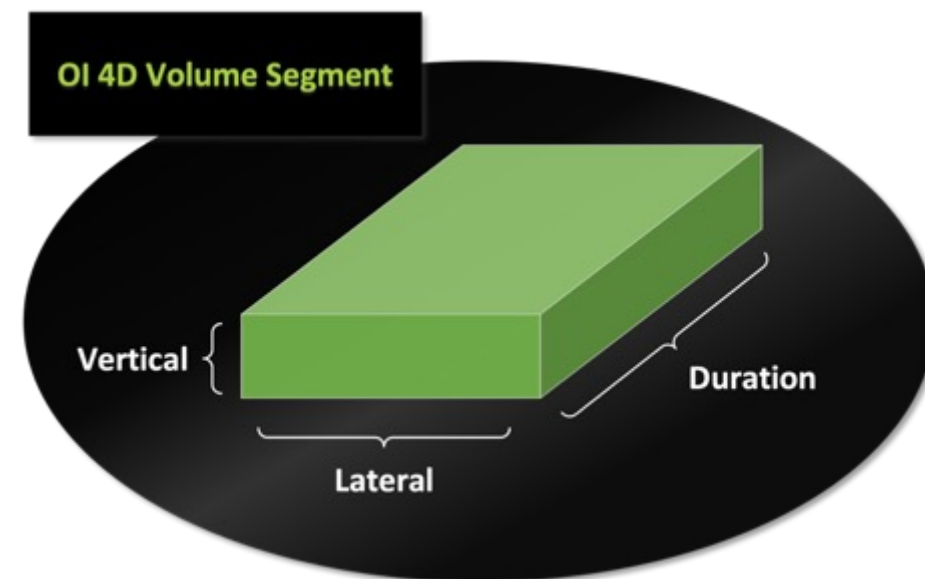
OI Requirements Based on Individual Preference or Common Standard

- Should the actual OI volume size be flexible and left up to the individual operators, or should there be a well-defined standard that is pre-determined?

  - By vehicle type?

- We heard from past activities that OI should be updated at standard, specified rates.

  - Do you agree?

  - Should the update rate be the same for <u>all</u> vehicle types, or the same by vehicle type?

Min/Max OI Volume Size by Vehicle Type

- We heard from previous work about proposed maximum OI volume sizes. In order to increase capacity in ETM, we need to gain a general understanding of min/max OI volume sizes that make sense based on <mark>active conformance to the 4DT within next 30 min to an hour.</mark>

- What are the min/max values for:

    - Balloons – lateral (nmi), vertical (feet), and update rate (minutes)

    - HALE FW – lateral (nmi), vertical (feet), and update rate (minutes)

    - Airships – lateral (nmi), vertical (feet), and update rate (minutes)

Details on Operational Intent (OI) Sharing via a Rolling Window

– What is a reasonable "rolling window" time duration (i.e., total OI duration) for each vehicle type: Balloons, HALE FW, and Airships?

– In our upcoming evaluation, we anticipate having a standardized update rate and rolling window timeframe that will be the same. Is there a reason to allow update rates to change while the duration stays the same?

– Would the update rate increase if there is a potential strategic conflict that needs to be resolved? If so, should the increased update rate be standardized? Does this differ by vehicle type?

Use of Containment Confidence Level (CCL) in Operational Intent (OI)

– Would OI volume CCL have an effect on the number of OI volumes that would be shared? How?

– Should OI volumes be required to have a high CCL for some initial time period? If so, for how far into the future? Does this differ by vehicle type?

– We assume CCL is calculated while the vehicle is actively conforming to the OI (if capable/possible). Do you agree with this assumption?

– If OI volumes have a low CCL, is it useful? What would be considered low CCL?

– How high does an OI volume confidence need to be in order to be considered useful?

Backup Slides

Rolling Window Background

- There have been many past discussions on the idea of a "rolling window", but no clear definition, so we want to get your input on what it could be …

  - It seems logical that each vehicle should have multiple OI volumes that extend multiple hours.

  - However, at some point into the future, conformance uncertainty of some operations could render the OI volume(s) not useful.

- Do you agree with this assessment? For which vehicles?

Operational Intent/Volumes

Purpose and usage

- How do you determine the OI volume size?
  - Agreement to be a "good citizen" and develop only OI volume sizes that are needed?
  - Size and duration of OI volume based on vehicle type? Should this be standard for all users by vehicle type?
  - <u>Min – max range of OI volumes for high confidence of conformance at different time horizons and update cycles – ranges for lateral and vertical. Identify for each vehicle type</u>

Generation by Operator: flexible and left up to the operator or pre-defined standard per vehicle type?

- Size lateral – fixed size for all vehicles? Fixed size per vehicle types? Size by CCL?
- Size vertical - What altitude stratum is reasonable for each vehicle type? Does it vary by type of operation?
- What time duration for each OI volumes? Should it be standardized, any length of time? Different by vehicle type?

Generation by Operator: Cont'd

- Rolling window: How many hours into the future make sense to share OI? (e.g. 2 hours? 4 hours?) What time duration makes sense for various vehicle types? Different for vehicle type?

Use of CCL in developing OI

- Does OI conformance confidence play into how many OI volumes would be shared?
- Should OI volumes have high conformance confidence for initial time period? If so, for how far into the future?
- We assume CCL is calculated while the vehicle is actively conforming to the OI (if possible). Is that a correct assumption?
- Degradation of CCL: If OI volumes have low CCL, is it useful? What would be considered low CCL?
- How high does an OI volume confidence need to be considered useful?

- OI and Waypoint Plan Generation
  - OI / 4DT has to be generated and distributed once they "commit to try" their mission
    - Inclusion of 4DT implies that all participants agree to provide something like a Waypoint Plan – confirm during our discussion
  - OI updated at a specified rate. Wants research to identify the rate.
  - OI update rate increases as time to conflict approaches nearer
    - What happens when there are more than other vehicles in the area not in conflict? Any issues with multiple vehicles with various update rates interacting with each other?
  - Once OI is submitted and accepted, the operator must conform to that intent and cannot change their intent unless new one is also approved

- Industry participants wants more details on the definition of "rolling intent"
  - It seems that they consider "rolling intent" as NASA's idea but don't know exactly what they are. We probably needs to define it further using a combination of number of OI volume segments and update cycle.
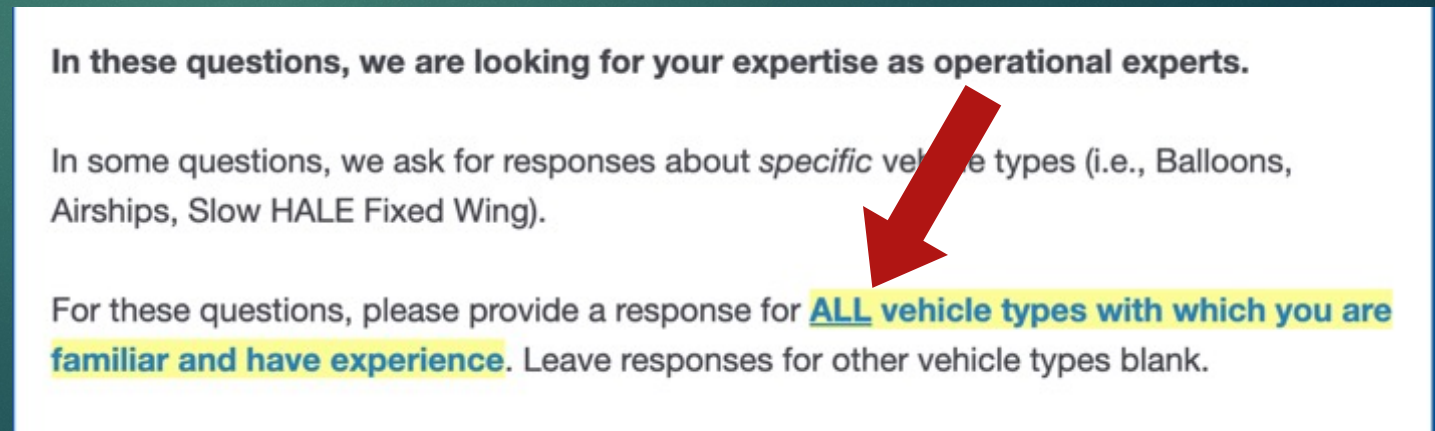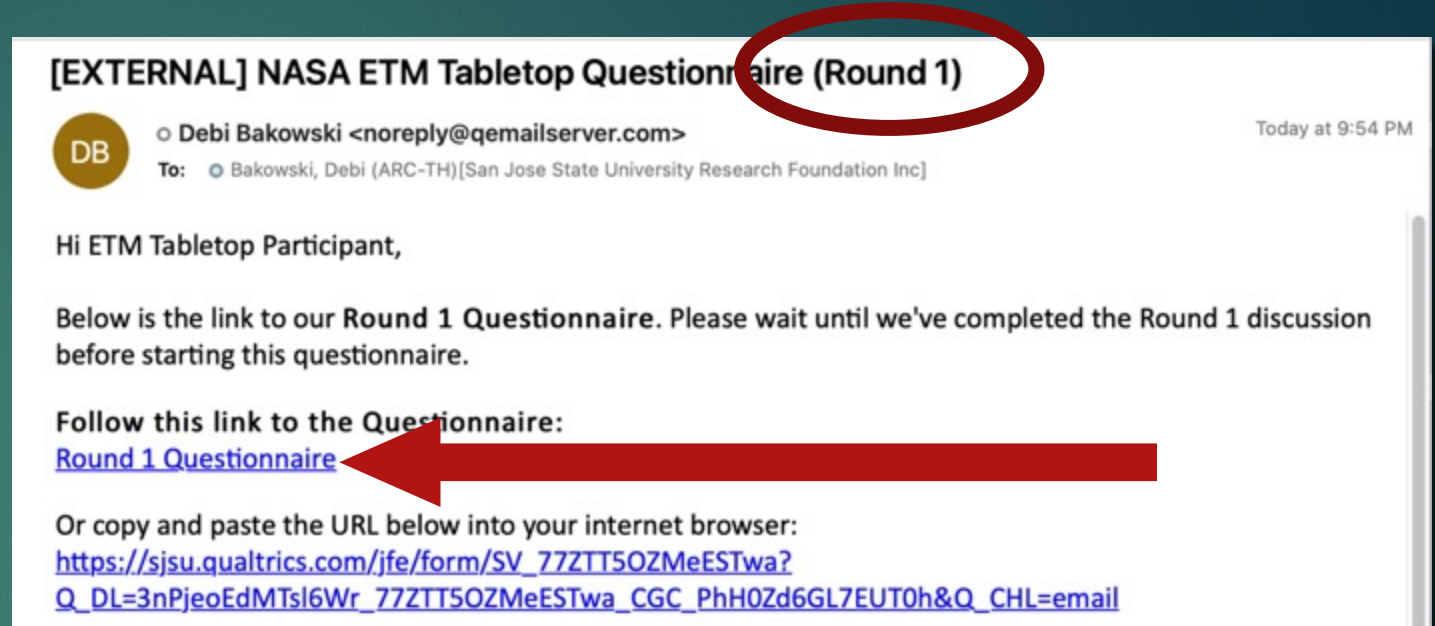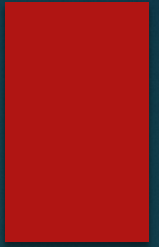
Round 1 Questionnaire

▶ Access through email link.

Vehicle-Specific Questions:

▶ Please provide a response for ALL vehicle types with which you are familiar.

▶ Leave responses for other vehicle types blank.

[EXTERNAL] NASA ETM Tabletop Questionnaire (Round 1)

○ **Debi Bakowski** <noreply@qemailserver.com>
Today at 9:54 PM
To: ○ Bakowski, Debi (ARC-TH)[San Jose State University Research Foundation Inc]

Hi ETM Tabletop Participant,

Below is the link to our **Round 1 Questionnaire**. Please wait until we've completed the Round 1 discussion before starting this questionnaire.

Follow this link to the Questionnaire:
Round 1 Questionnaire

Or copy and paste the URL below into your internet browser:
https://sjsu.qualtrics.com/jfe/form/SV_77ZTT5OZMeESTwa?
Q_DL=3nPjeoEdMTsl6Wr_77ZTT5OZMeESTwa_CGC_PhH0Zd6GL7EUT0h&Q_CHL=email

In these questions, we are looking for your expertise as operational experts.

In some questions, we ask for responses about *specific* vehicle types (i.e., Balloons, Airships, Slow HALE Fixed Wing).

For these questions, please provide a response for **ALL vehicle types with which you are familiar and have experience**. Leave responses for other vehicle types blank.

End of Day 1 Recap

► Online Survey for Round 1 Questions?

► Training and Lexicon for developing Operational Plan, specifically Operational Intent Volumes and needed characteristics

► Operation Plan (OP) Parameters

► Operation Intent (OI) Volume Generation Parameters

  ► Containment Confidence Level (CCL)

  ► Flight Info Update Rate

    ► OI Segment Update Rate

    ► OI Segment Duration

    ► OI Segment Size Restriction

    ► Total OI Time Horizon

► ETM System

  ► Submit OP/OI

  ► System Response

Day 2 Agenda Overview: Round 2

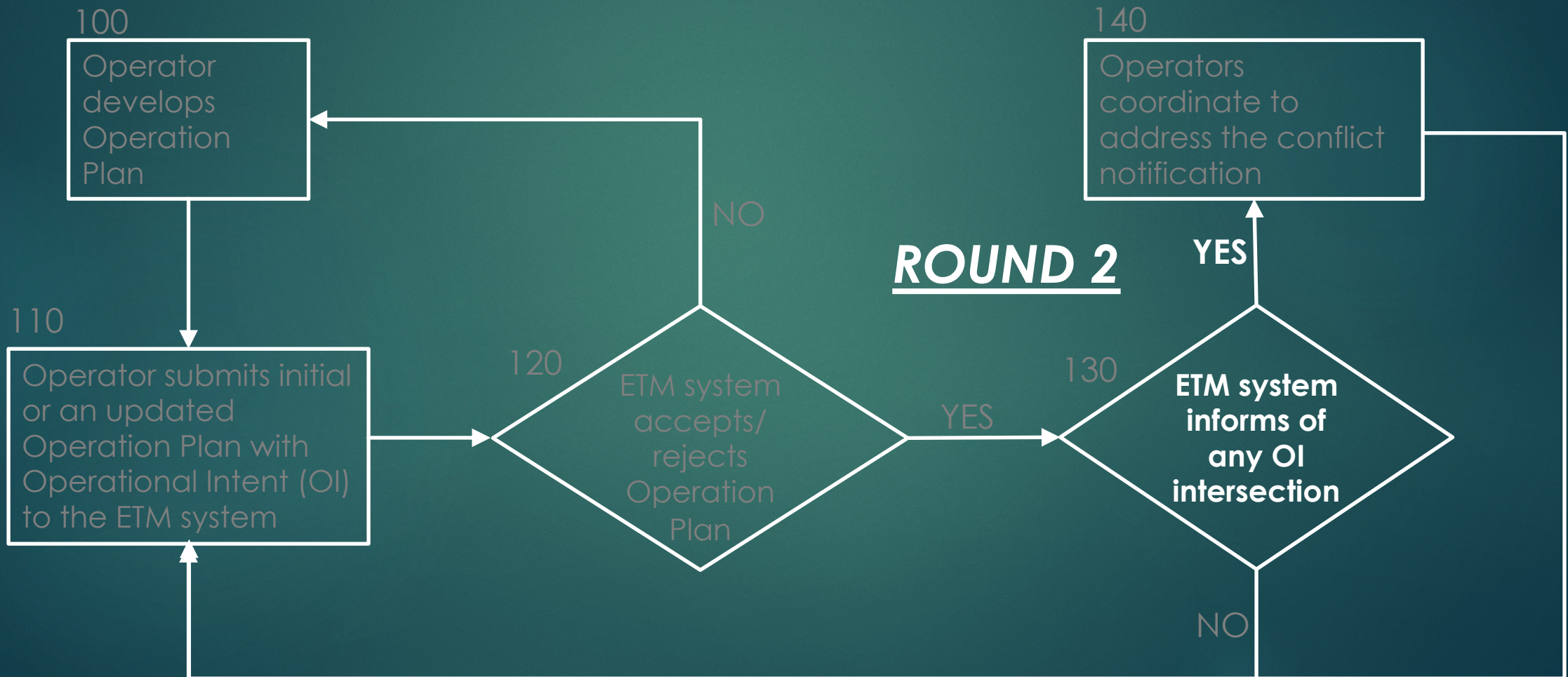| Day 2: January 11, 2022 (9am – 1pm PDT)		
Round 2: Strategic Conflict Detection	**~2 hours**	
- Welcome Back and Training/Familiarization	30 min	Connie
- Discussion	75 min	Paul
▪ OI Intersect		
▪ OI Intersect Triggers		
▪ Conflict Probability/Likelihood		
▪ Assess Parameters and Decision Points		
- Online Questionnaire	10 min	
Break	15 min	
Round 3: Cooperative Operating Practices (COPs) for Strategic Deconfliction	**~2 hours**	
- Training/Familiarization	15 min	Connie
- Discussion	70 min	Mark
▪ NASA and AIA Draft COPs		
▪ General Assumptions for COPs		
▪ Iterative Walkthrough of 3 Types of COPs		
▪ COPs Process/Agreement/Actions/Formats		
- Online Questionnaire	10 min	
Tabletop Wrap-Up	15 min	

ETM Tabletop Lexicon (cont.)
Day 2~

- *Strategic Conflict 'Detection':* Two or more OI volumes intersect in space and time

- *Strategic 'Deconfliction'*: methods to strategically solve OI intersection

- Conflict Probability: likelihood of vehicles getting close within a defined separation standard or Likelihood of vehicle conflict based on predicted vehicle paths, calculated independently from OI Intersection calculations

- *Conflict Probability Alert Setting Thresholds*: The pre-defined parameters to notify the operators of the estimated proximity of another vehicle

- *Separation Envelope*: distance between predicted vehicle locations that would trigger the alert

- *Flight Information Update Rate*: regular and frequent updates to active flight telemetry data are important for the OI Intersect and/or conflict probability calculations in the ETM system

- *Assess the Strategic Conflict*: given OI volume intersect and/or conflict probability alert information, the operator will weigh the options

- *Decision Point*: the collaborative resolution time allowed when considering the assessed information and whether to 'wait-and-see' or 'take-action' (enact COPs)

- *Cooperative Operating Practices (COPs):* set of pre-agreed operating rules and procedures to maintain separation while promoting safety, cooperatively, fairly and equitably

Tabletop Training: Round 2
130~ Operational Intent Intersection

Strategic Conflict 'Detection'

100 — Operator develops Operation Plan

110 — Operator submits initial or an updated Operation Plan with Operational Intent (OI) to the ETM system

120 — ETM system accepts/ rejects Operation Plan

NO

YES

130 — ETM system informs of any OI intersection

ROUND 2

140 — Operators coordinate to address the conflict notification

YES

NO

Strategic Conflict 'Detection'
ETM System Response to OI Intersect (130)

▶ **ESS Responses to Operator**

    ▶ Proposed: This operation is not yet ACCEPTED. It may be awaiting information, or for some other reason it is not yet able to be declared ACCEPTED.

    ▶ Rejected: something in plan is not valid – wrong format, outside defined limits etc...

    ▶ Accepted (no OI conflict detected): indicates that the OI meets all requirements to access and operate in the ETM environment but is not yet in operation.

    ▶ **Accepted with OI intersect**

    ▶ Activated

    ▶ Conforming

    ▶ Nonconforming

    ▶ Contingent

    ▶ Closed

Operations

▶	gufi	callsign	state	control	ccl	oicp threshold	OI Intersect
▼	112d	AIRSHIP001	Accepted	cancel connect activate close	0.95	0.35	0.49

Strategic Conflict 'Detection' Round 2
OI Intersection (130)
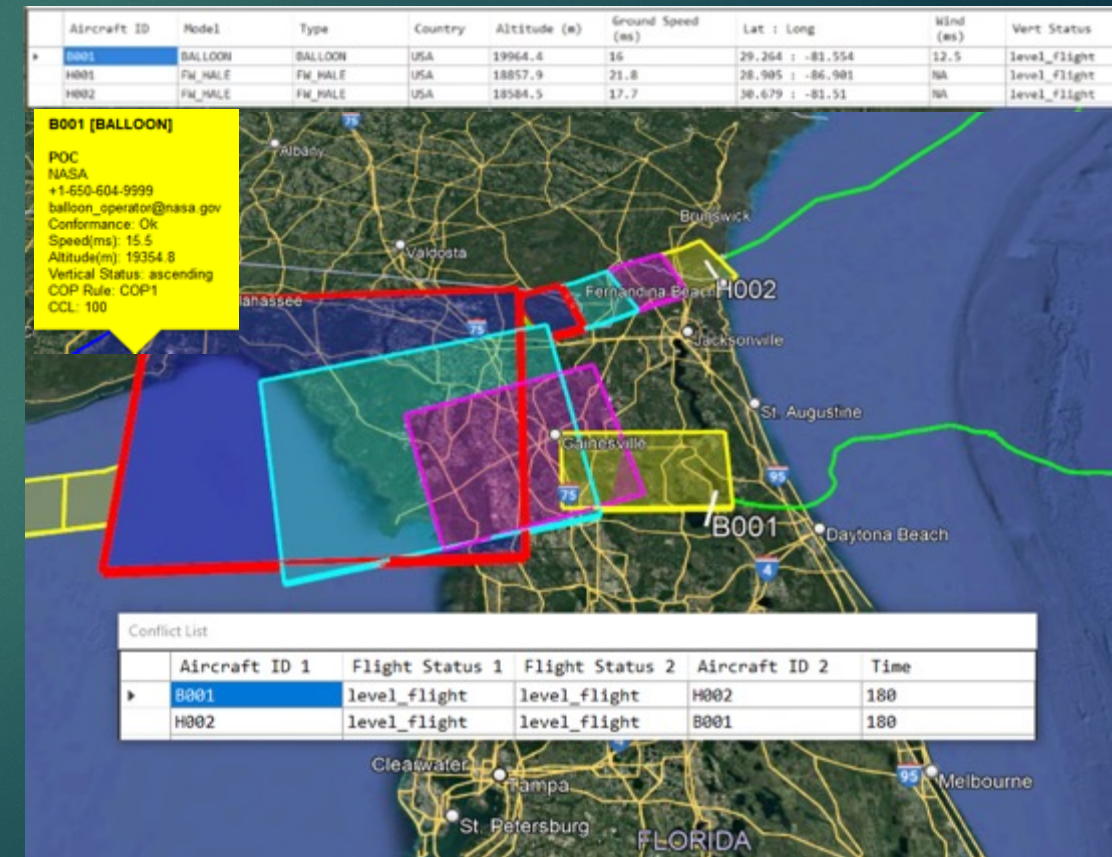
▶ Strategic Conflict: Two or more OI volumes intersect in space and time

▶ ESS Notifies each operator of Intersection in timely manner (TBD)

    ▶ Prompts notification based on some preset criteria

        ▶ Only show me....when (individual threshold settings)

            ▶ Risk tolerance driven

            ▶ Fairness/Equity issues arise

        ▶ Cooperative Standard (community defined threshold settings)

            ▶ Based on high-risk operational parameters

            ▶ Vehicle-to-vehicle type
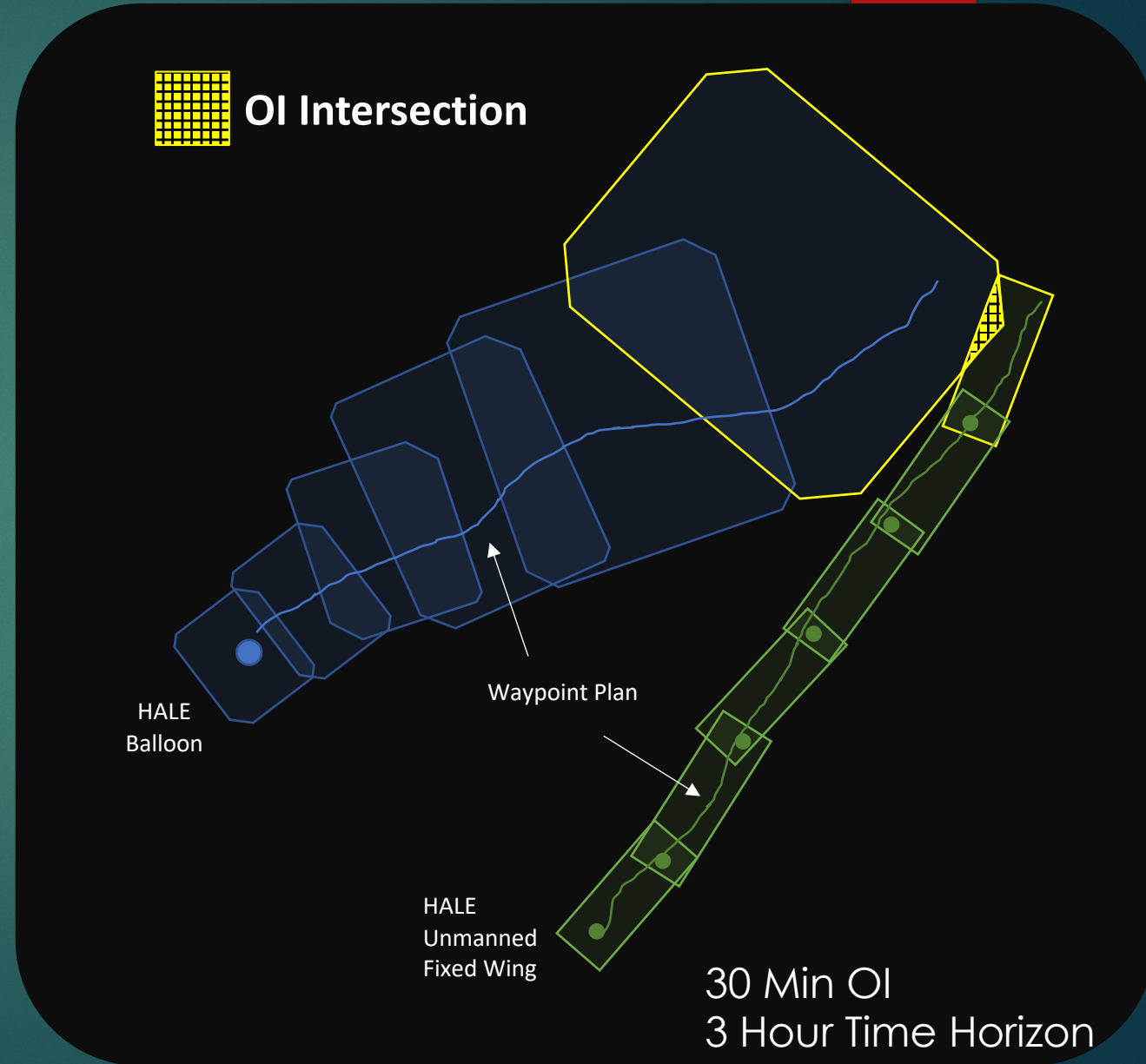
Impact of OI Intersection: Triggers

- OI Characteristics
  - Size of OI
    - Width/Height (spatial)
    - Length (temporal)
  - OI update cycle
  - OI time horizon (total # of segments)

- OI Volume Intersection information
  - Conflicting vehicles Operation Plan
  - Time horizon of the intersection
  - Geometry of the intersection
  - Confidence level of the intersection

OI Intersection

Waypoint Plan

HALE Balloon

HALE Unmanned Fixed Wing

30 Min OI
3 Hour Time Horizon

Operational Intent Intersect

Intersect Vehicle Pair	B001/H002
Intersect Geometry	15 %
Time Horizon to Intersect	180 min
Confidence Containment Level	55%/100%

Impact of OI Intersection: Triggers Smaller OI and Time Horizon

OI Intersection

10 Min OI
1 Hour Time Horizon

Operational Intent Intersect

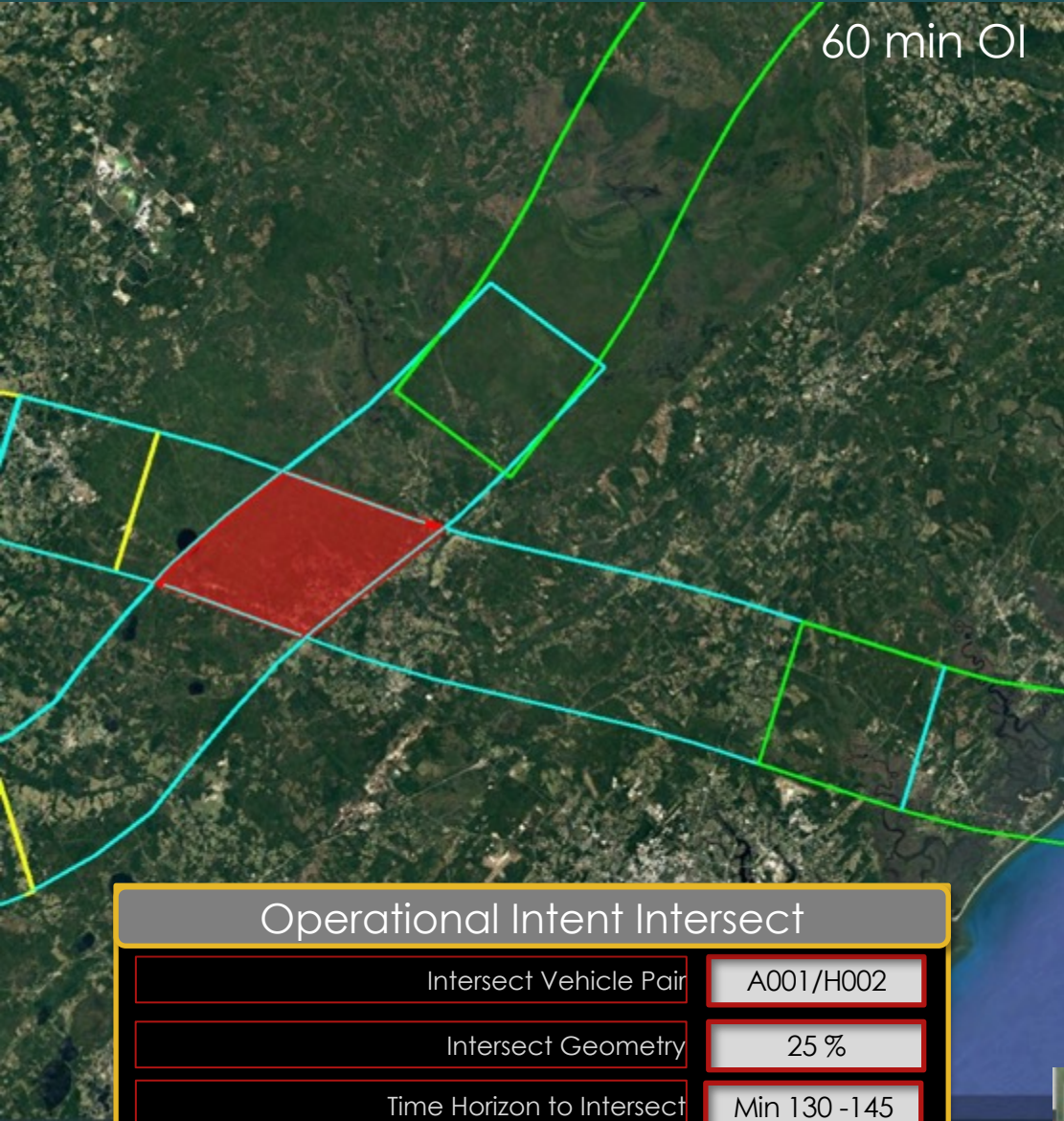|	
Intersect Vehicle Pair	B001/H002
Intersect Geometry	15 %
Time Horizon to Intersect	60 min
Confidence Containment Level	95%/100%

HALE
Balloon

Waypoint Plan

HALE
Unmanned
Fixed Wing

60 min OI

60 min OI
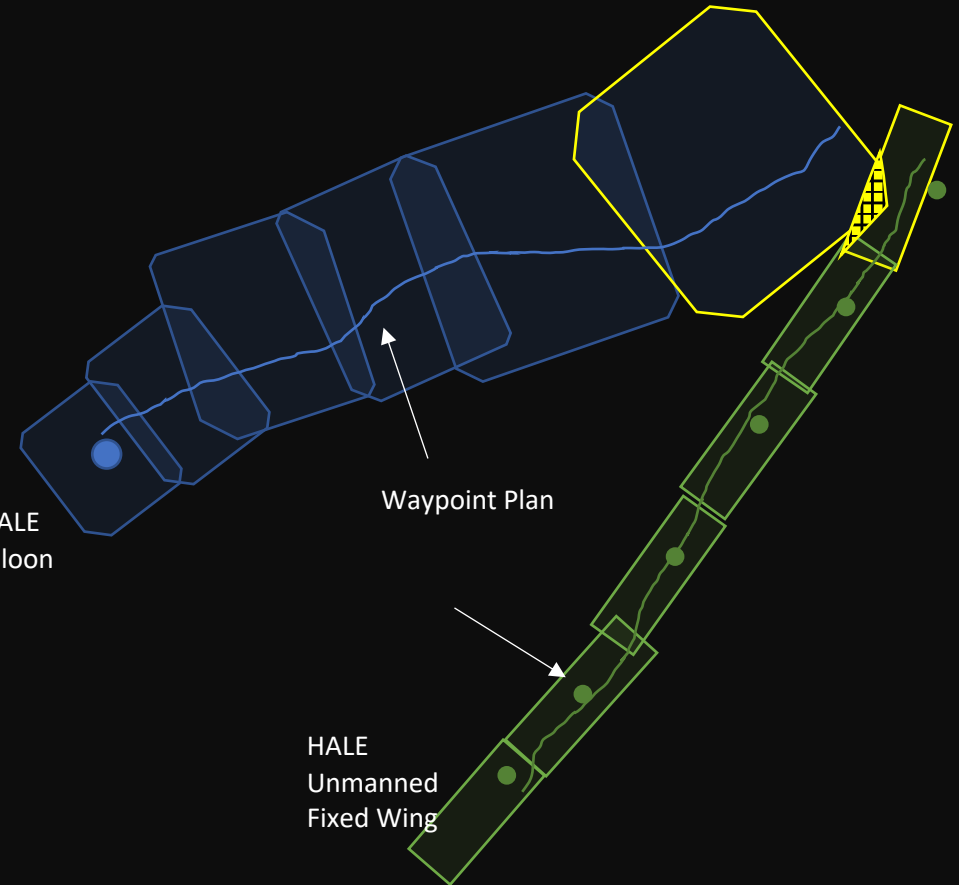
Operational Intent Intersect

|	
Intersect Vehicle Pair	A001/H002
Intersect Geometry	25 %
Time Horizon to Intersect	Min 130 -145
Confidence Containment Level	95%/100%

Aircraft ID 1	Flight Status 1	Flight Status 2	Aircraft ID 2	Time
H001	level_flight	level_flight	A002	120

Conflict Probability/Likelihood

▶ Conflict Probability: Likelihood of *vehicle conflict* based on predicted vehicle paths calculated independently from OI Intersection calculations

- ▶ Likelihood of actual vehicle buffer separation
- ▶ Separation envelope- distance between predicted vehicle locations that would trigger the conflict
- ▶ Time horizon of the conflict prediction

▶ Based off Industry sharing:

- ▶ Waypoint Plan (lat/long, alt, spd)
- ▶ Trajectory Performance
    - ▶ Cross Track Error stays constant depending on the lateral control performance
    - ▶ Along Track Error flying at a constant airspeed can increase / decrease depending on the wind errors
- ▶ Wind Forecast Error (Assumed Common Source)
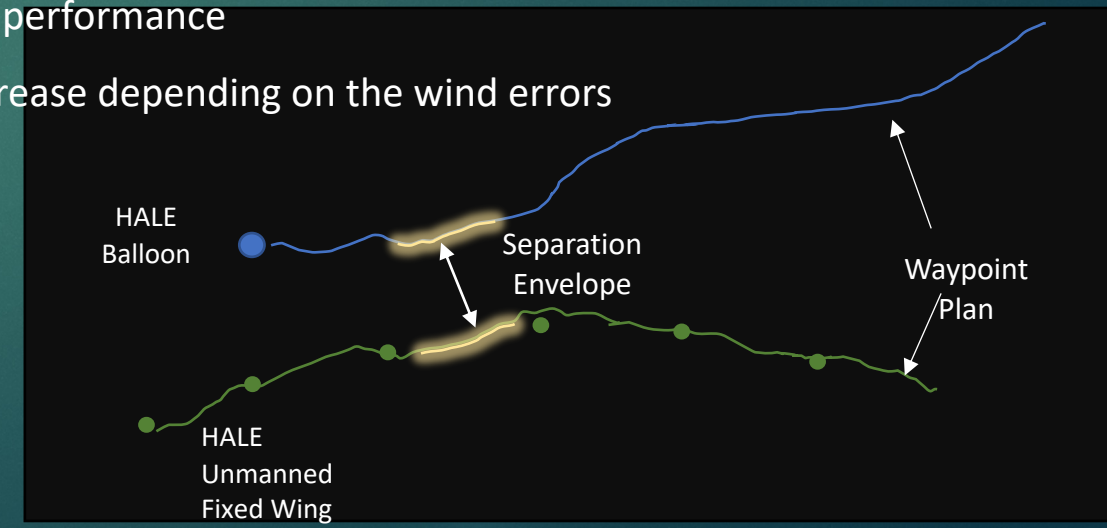
Conflict Probability/Likelihood
CP <u>Common</u> Threshold Settings

Conflict Probability Alert Setting

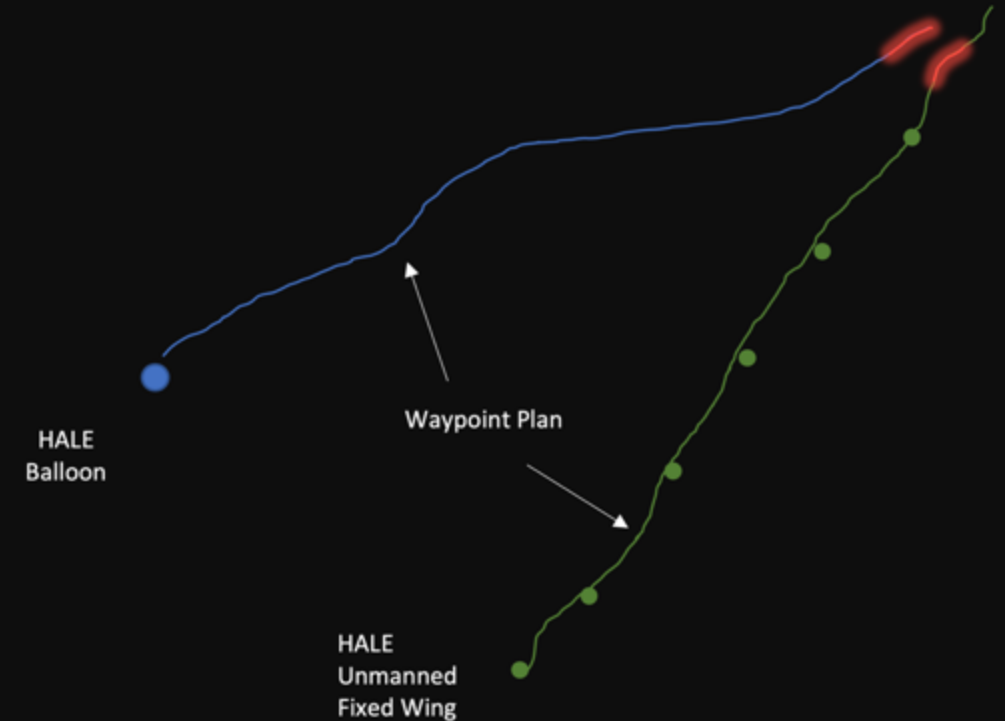|	
Minimum Separation Thresh (nmi)	10 nmi
Conflict Probability Thresh (%)	60 %
Look-ahead-time Thresh (minute)	180 min

- ▶ How to use Conflict Probability/Likelihood

- ▶ CP needs threshold parameters based on some criteria

    - ▶ CP % threshold (~ Set at 60% for this example)

        - ▶ Red <u>></u> 60%

        - ▶ Yellow would be anything within ½ of that ~30-59%

        - ▶ Green < 30%

    - ▶ Time to Conflict

        - ▶ CP look-ahead-time threshold

    - ▶ Separation Envelope (Set at 10 nmi)

        - ▶ Minimum closest approach distance (7 nmi) of flight path

- ▶ ESS Alert Triggers to <u>Both</u> Operators

Conflict Probability	
Conflict Probability	**80%**
Time to Conflict	**180 min**
Closest Approach	**7 nmi**

HALE Balloon

Waypoint Plan

HALE Unmanned Fixed Wing

Conflict Probability/Likelihood
CP Individual Threshold Settings

H002 Conflict Probability Alert Setting

Minimum Separation Thresh (nmi)	10 nmi
Conflict Probability Thresh (%)	60 %
Look-ahead-time Thresh (minute)	180 min

B001 Conflict Probability Alert Setting

Minimum Separation Thresh (nmi)	5 nmi
Conflict Probability Thresh (%)	85 %
Look-ahead-time Thresh (minute)	90 min

Conflict Probability

Conflict Probability	**80%**
Time to Conflict	180 min
Closest Approach	**7 nmi**

ESS would Alert the Slow Hale
Balloon would not be Alerted

HALE
Balloon

Waypoint Plan

HALE
Unmanned
Fixed Wing
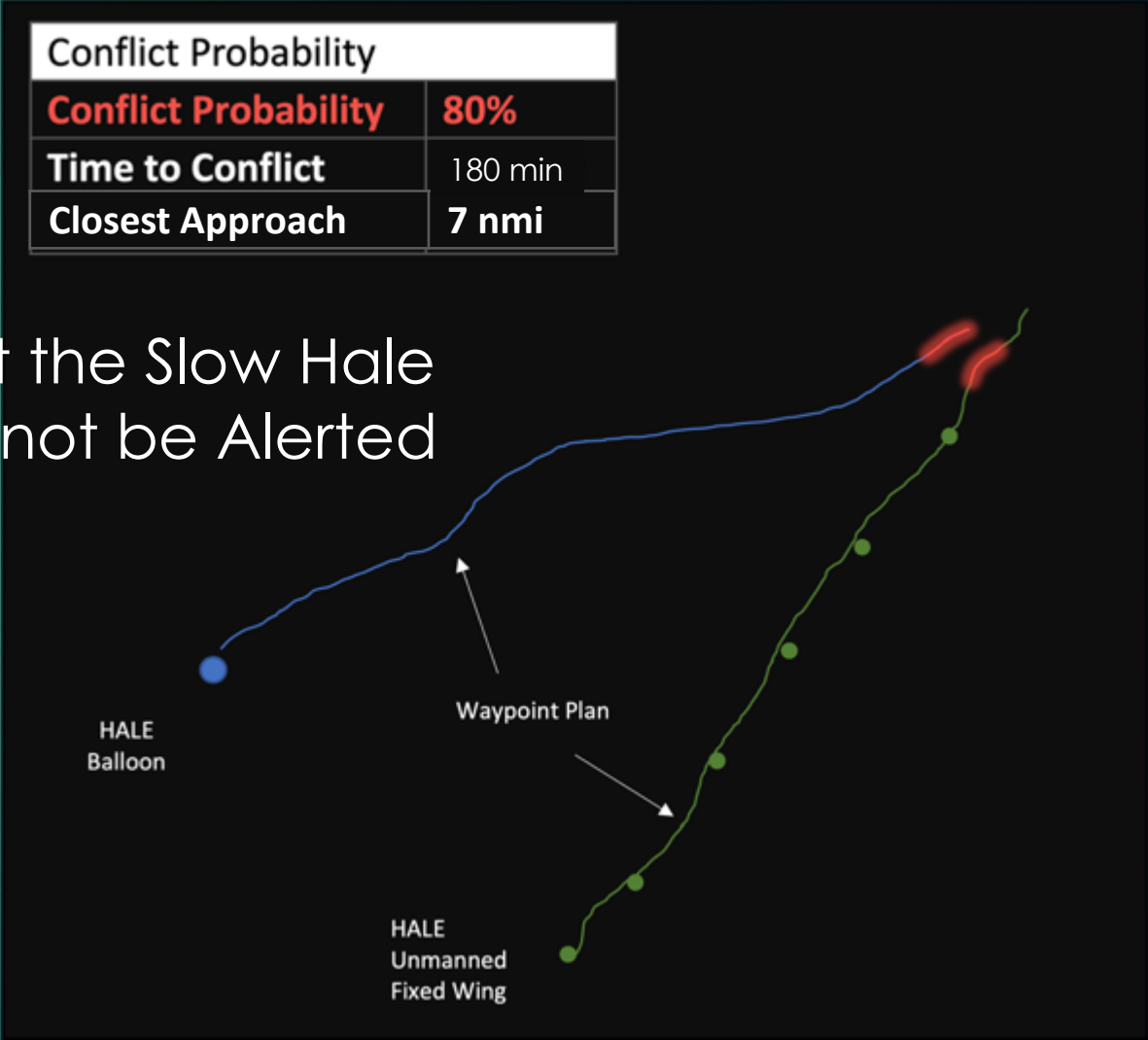
Time to Conflict — Near → Far

Conflict Probability — Low → High

Panel (top-left):

Conflict Probability	
Conflict Probability	30%
Time to Conflict	90 min
Closest Approach	10 nmi
Confidence Level CCL	95 %

OI Intersection	
Yes	

HALE Balloon
HALE Unmanned Fixed Wing
Waypoint Plan

Panel (top-right):

Conflict Probability	
Conflict Probability	30%
Time to Conflict	180 min
Closest Approach	10 nmi
Confidence Level CCL	65 %

OI Intersection	
Yes	

HALE Balloon
Waypoint Plan
HALE Unmanned Fixed Wing

Panel (bottom-left):

Conflict Probability	
Conflict Probability	80%
Time to Conflict	90 min
Closest Approach	7 nmi
Confidence Level CCL	95 %

OI Intersection	
Yes	

HALE Balloon
Waypoint Plan
HALE Unmanned Fixed Wing

Panel (bottom-right):

Conflict Probability	
Conflict Probability	80%
Time to Conflict	180 min
Closest Approach	7 nmi
Confidence Level CCL	65 %

OI Intersection	
Yes	

HALE Balloon
Waypoint Plan
HALE Unmanned Fixed Wing

OI Intersection | **Conflict Probability**

Operational Intent Intersect

Intersect Vehicle Pair	B001/H002
Intersect Geometry	15 %
Time Horizon to Intersect	180 min
Confidence Containment Level	65%/100%

Conflict Probability Alert Setting

Minimum Separation Thresh (nmi)	10 nmi
Conflict Probability Thresh (%)	60 %
Look-ahead-time Thresh (minute)	180 min

Conflict Probability/Likelihood Videos
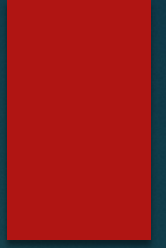
Assess Situation: 'Wait-and-See' or 'Act' (Initiate COPs)

▶ ESS Notifies with Intersecting OI information (to assess action needed)

  ▶ Conflicting Vehicle/Company Operation's Plan

  ▶ The geometry of the OI Intersection (where and how much it is intersecting)

  ▶ Start and end time of the conflict

  ▶ Containment Confidence Levels of the intersecting OIs

  ▶ Probability/likelihood of flight intent intersection

Decision Point-
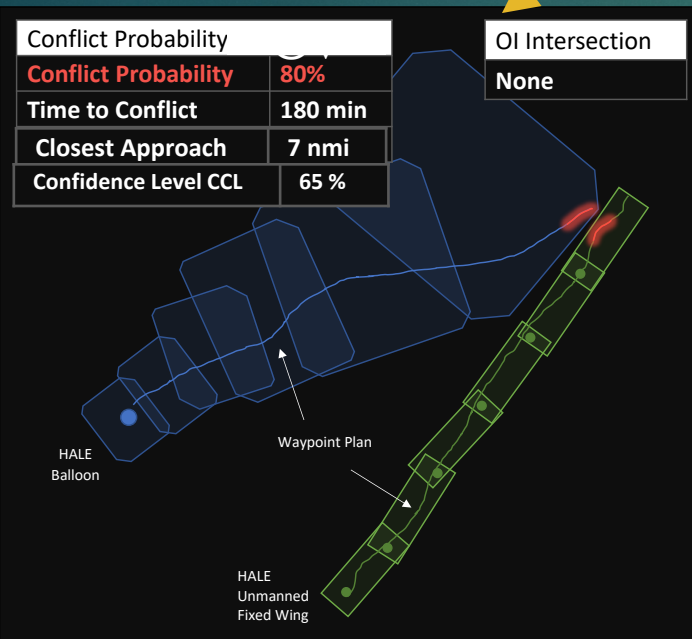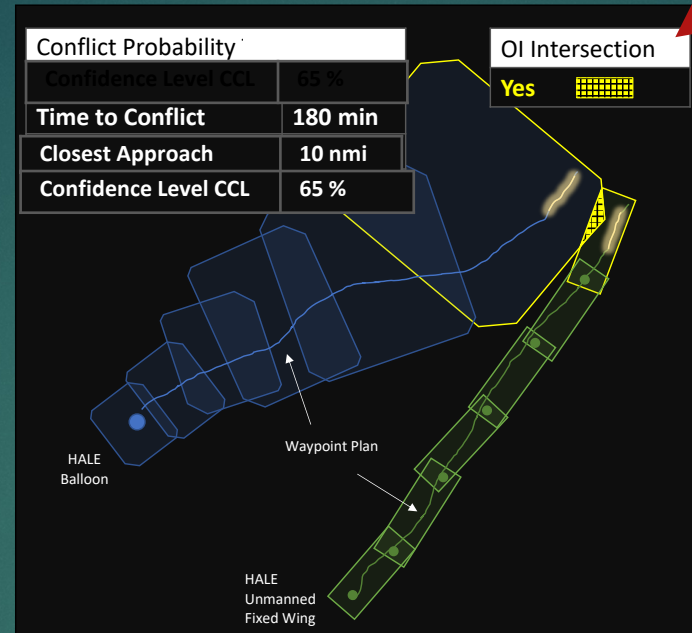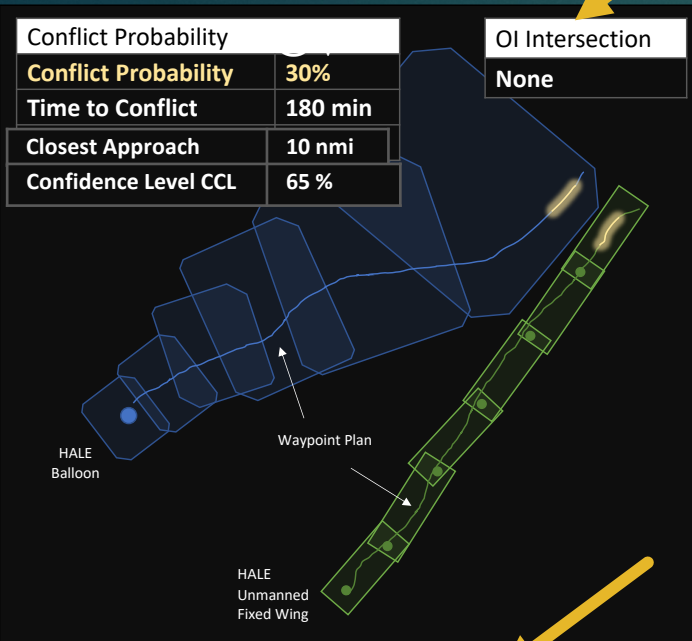
▶ Would OI Intersect be the Prime Trigger?

▶ Could CP trigger the alert by itself with No OI Intersect??

Decision Point-Initiate COPs

- Factors to resolve the conflict:
  - Conflict Probability
  - Conflict look-ahead time
  - Closest Approach
  - CCL values

  - Round 3: Codify Cooperative Operating Practices
    - Ad-hoc Negotiation
    - Pre-Agreed Negotiation
    - First Reserved, First Served

Conflict Probability Thresholds	
Conflict Probability	80%
Time to Conflict	180 min
Closest Approach	7 nmi
Confidence Level CCL	65%

OI Intersection	
Yes	

HALE Balloon

Waypoint Plan

HALE Unmanned Fixed Wing

Conflict Probability	
Conflict Probability	80%
Time to Conflict	180 min
Closest Approach	7 nmi

OI Intersection
Yes

HALE Balloon
Waypoint Plan
HALE Unmanned Fixed Wing
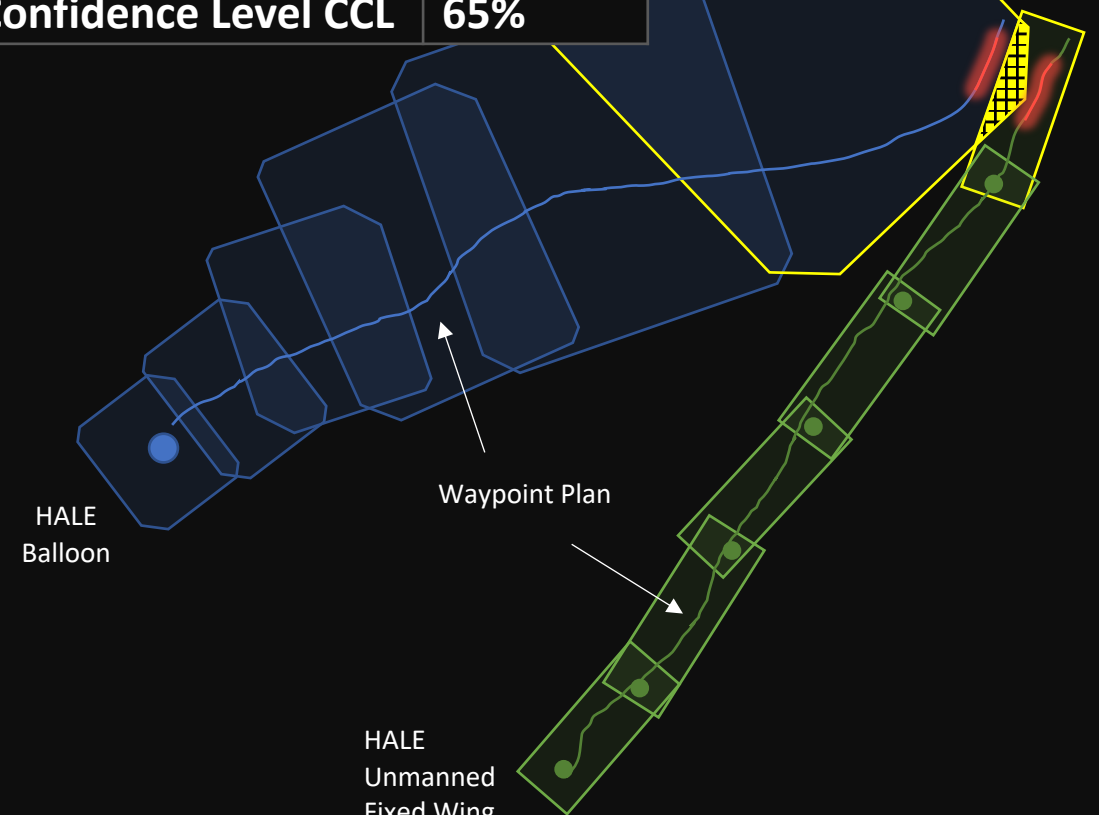
Round 2

Operator 2 submits an Operation Plan. The ESS detects an intersection with another OI.

Operators take no action.

- Scenario for Round 2 (100/110/120/130)
  - Query the system for other operations
  - Build OP (actively work to make conflict free?)
  - Submit OP/OI
  - **Accepted _with_ Conflict**
    - **Strategic Conflict 'Detection' OI Intersect**
    - **Probability/Likelihood of actual vehicle conflict**
    - **Assess Situation**
    - **Decision Points (wait-and-see)**
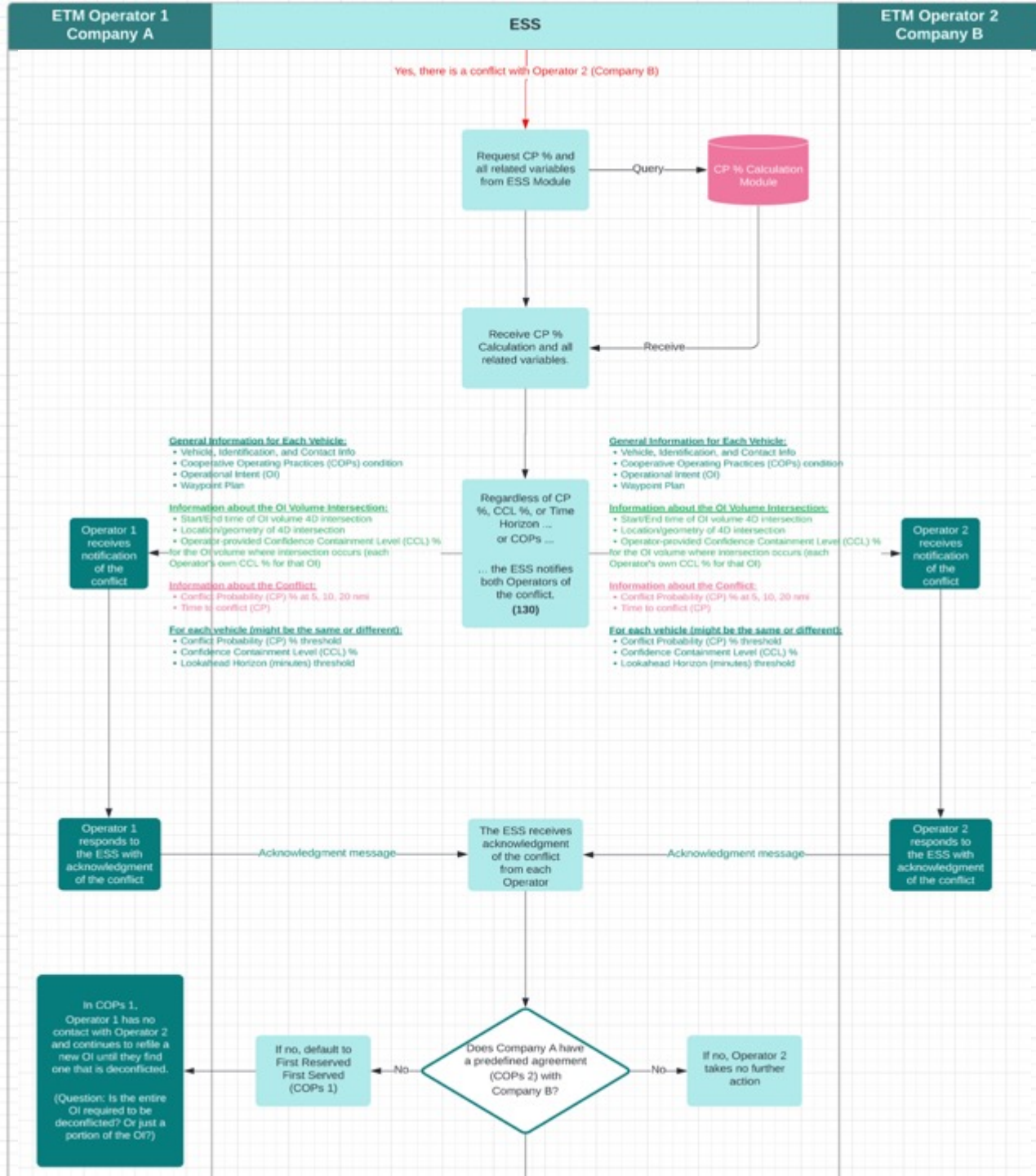
Detailed Discussion Questions Round 2
Paul Lee
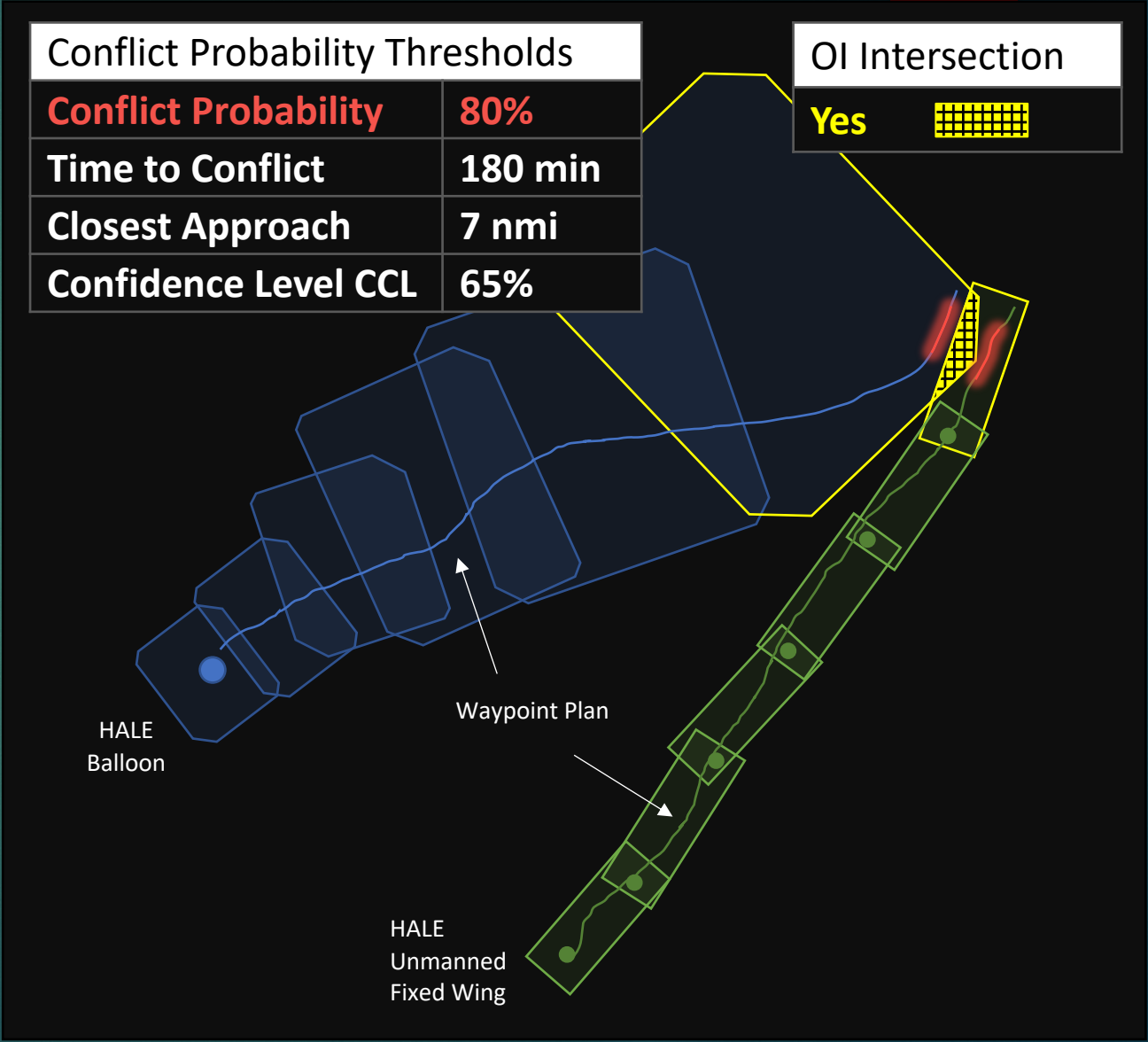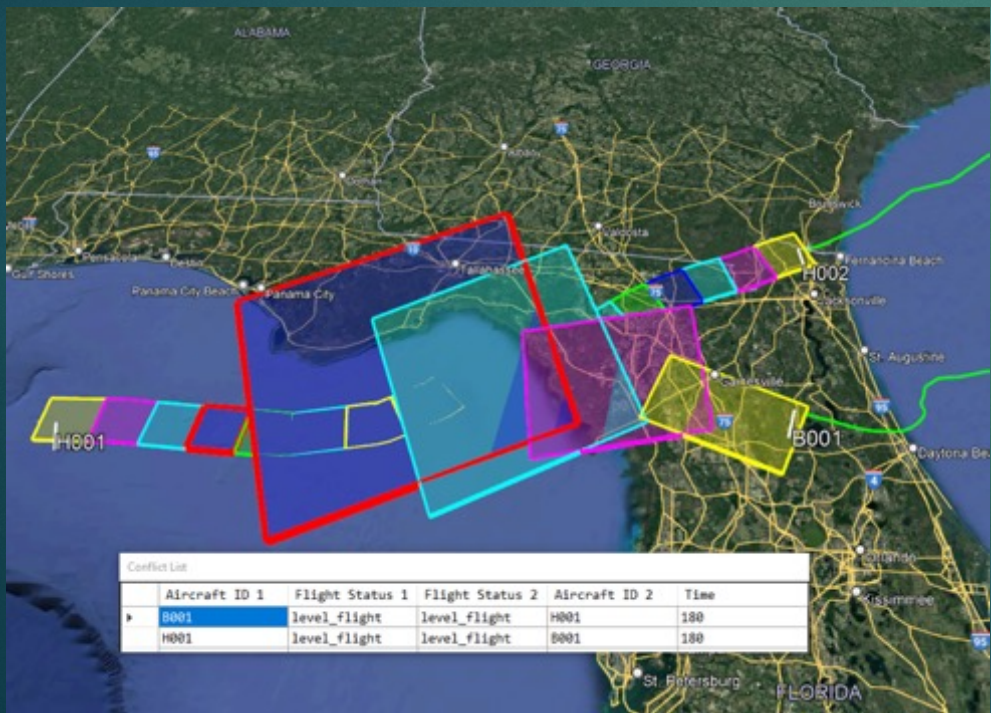
Conflict Probability Thresholds	
Conflict Probability	**80%**
Time to Conflict	**180 min**
Closest Approach	**7 nmi**
Confidence Level CCL	**65%**

OI Intersection	
Yes	

Waypoint Plan

HALE
Balloon

HALE
Unmanned
Fixed Wing

Round 2: Strategic Conflict Detection

Primary Focus

- Triggering Strategic Conflict Detection based on OI Volume Intersections

- Establishing Common Assumptions for Strategic Conflict Detection

- Establishing Separation Envelopes between Vehicle Pairs for Strategic Deconfliction

Additional Questions

- Visual Information Required for the Vehicle Operators about the Strategic Conflict

- Use of the 4DT and Waypoint Plan for Conflict Probability Calculations

- Understanding Factors for Deciding Whether to Wait-and-See vs. Initiate COPs

- Coordinating Wait-and-See vs. COPs Initiation

OI Intersection

Agreement on OI Intersection as the Trigger for COPs

– Do you think / agree that <u>an intersection of OIs</u> should be the event that initiates the strategic conflict assessment and determines whether COPs should be initiated?

– Should OI size and characteristics be standardized so that the detection of OI intersections occurs consistently for given vehicle type pairs regardless of who submitted the OIs?

Conflict Probability

Common Standards vs. Individual Preferences for Conflict Probability

– Do you think / agree that an independent method of calculating the conflict likelihood (Conflict Probability) is a good idea in addition to detecting OI intersections?

– Should a common Conflict Probability calculation be used to provide the same conflict likelihood results for the vehicle pairs in conflict? Or is it ok for each vehicle operator to have different Conflict Probability results based on their own data and threshold settings?

Conflict Probability

Which Information Should be Common or Standard?

– Which of the following information and/or calculations, if any, should be common or standard for the vehicle pairs in conflict?

- Conflict Probability Information:

  – Common method for calculating Conflict Probability

  – Standard separation envelopes (i.e., safe distance) between the vehicles for different combinations of vehicle pairs.

- Common wind data (which ones and how to share them?)

- Sharing of vehicle performance and/or other information (which ones?)

Safe Separation Envelopes for Conflict Probability Calculation

– For the Conflict Probability calculations, what should the <u>separation envelope</u> (distance in nmi) be between each of the following vehicle pairs:

- Balloon vs. Balloon (Same or different within the same vs. different companies?)

- Airship vs. Airship (Same or different within the same vs. different companies?)

- HALE FW vs. HALE FW (Same or different within the same vs. different companies?)

- Balloon vs. Airship

- Balloon vs. HALE FW

- Airship vs. HALE FW

OI Intersection **Conflict Probability**

What Information do Vehicle Operators Need for Assessment?

– Once the OI intersection is detected and Conflict Probability is calculated, what information do the vehicle operators need to see a visual representation of? Following is some of the information available:

- Information about vehicle in conflict – vehicle type, ID, operating company, etc.

- OI intersection – time window of the intersection, intersection geometry, CCL (Containment Confidence Level), percentage of OI intersection overlap

- Conflict Probability – estimated time to conflict, conflict probability value, separation envelopes between vehicles

- Wind source and other environmental data used for calculations?

- Other information?

– How would the information be used for the operators' decision making?

4DT and Waypoint Plan

- Our Conflict Probability calculations need the operator to share their Waypoint Plan, which includes vehicle's predicted 4D trajectory and vehicle performance information.

  - In your opinion, would an ETM operator be willing to:

    - Share your vehicle's predicted 4D trajectory with the ESS, at a regular update rate, for accurate Conflict Probability calculations?

    - Share other trajectory-related information, such as your vehicle performance and error characteristics (e.g., cross-track error), that might be needed for accurate Conflict Probability calculations?

  - If an ETM operator would be willing to share their 4D trajectory, would they do that by sharing with other operators via the ESS, via a third-party service, or directly with other operators?

Coordination between Vehicles in Strategic Conflict (OI Intersection)

- Should there be a mechanism for operators to let the ESS know if they decide to wait-and-see vs. initiate COPs, or is it assumed based on the situation?

- Do both operators have to agree to decide together to wait-and-see vs. initiate negotiation?

- Can one vehicle remain in wait-and-see while the other is in negotiation?

Coordination when one Operator Takes Action to Resolve

– Are there situations in which a vehicle operator will decide to resolve a conflict instead of wait-and-see?

• If so, do they need to initiate COPs negotiation with the other vehicle?

• If one vehicle decides to update its OI to resolve the OI intersections, even in a situation with low Conflict Probability and/or a long time until the intersection, does the operator need to coordinate the action with the other vehicle?

OI Intersection   Conflict Probability

Factors that Impact Wait-and-See vs. Initiate COPs

- Which of the following information would be used to determine whether or not to initiate COPs now?

    - Conflict Probability: Conflict Probability value, separation envelopes used for the calculation

    - OI Intersection: time window of the intersection, intersection geometry, CCL (Containment Confidence Level), percentage of OI intersection overlap

    - Vehicle type, etc.

- Should there be pre-established procedures or an agreement in the COPs that provides a consistent outcome on when to wait-and-see vs. initiate COPs negotiation?

Backup Slides

Trigger event for evaluating potential strategic conflict detection
- Use OI volume intersection as the trigger event – is that ok? Should OI size be standardized to allow more consistent detection of OI volume intersections?
- Should we use anything else as a trigger event instead?

Which factors should weigh into whether to take an action to resolve the conflict?
- OI Volume Intersection info
  - Time horizon of the intersection
  - Geometry of the OI volume intersection
  - CCL of the overlapping OI volume intersections

- Conflict Probability - Likelihood of vehicle conflict based on predicted vehicle paths calculated independently from OI volume intersection calculations
  - Likelihood of the conflict probability
  - Time horizon of the conflict prediction
  - Separation distance triggers based on predicted vehicle locations

- Other factors – e.g. visual display of the OI volume intersection or other parameters to the human operators
- Need a decision support tool to display OI volumes for human operators? Reviews done only by automation?
- What are the key parameters to 'trigger' strategic conflict 'detection'?
- Should the parameters that impact the conflict trigger and actions to resolve the conflict be standardized or user settable? (e.g. OI size, conflict separation distance, risk tolerance, etc.)

Should there be any rules (COPs) on whether/when an operator should take actions once OI volume intersection is detected? Is it completely look-ahead time driven?
- Should there be timeframes at which operators are required to respond to the possible OI volume intersection by "negotiating" with the other operator? Is the decision completely independent?
- Are any rules about entering into a 'wait and see' mode based on vehicle type or are decisions purely operator preference?

Does a 'wait and see' (no action now) decision lead to other required actions?
- Does it need to be communicated to the other operator and or the ESS?
- Is there a specific time to re-visit the decision?
- Do both parties need to agree on the no action using COPs?
- Does the ESS have an obligation to update notification of OI volume intersection at some interval? (e.g., snooze for 'x' update time)
- Is there a timeframe when negotiating via a COPs is required? (Prior to the unilateral required response action)

GENERAL QUESTIONS
- Can vehicles from the same company operations be closer together than vehicles between companies? If so, why?
- Per vehicle type, are there multiple separation requirements based on the conflicting vehicle, the operating company of the vehicle, etc.? Or should there be a pre-established common standard?

- Separation Distance Threshold
  - Balloons
    - Desire clusters of balloons within a fleet (instead of individual flights)
    - Little separation (e.g. 1/3 nm) needed between balloons (within the same fleet)
    - What about the distance between Balloons by different operators?
  - HALE FW
    - Likely single vehicle operations
    - Separation between HALE FW are likely to be 10s of nm (e.g. 40 nm)
    - What about HALE FW and Balloons?

- Method for Strategic Conflict Resolution
  - Start with ad-hoc negotiation and move onto automated process based on lessons-learned
    - We probably want to introduce pre-agreed coordination as a bridge in-between and first-reserved, first-served for the "tactical region" of the OIs as a default

Round 2 Questionnaire

▶ Access through email link.

Vehicle-Specific Questions:

▶ Please provide a response for ALL vehicle types with which you are familiar.

▶ Leave responses for other vehicle types blank.

[EXTERNAL] NASA ETM Tabletop Questionnaire (Round 2)

○ **Debi Bakowski** <noreply@qemailserver.com>   Today at 9:56 PM
To: ○ Bakowski, Debi (ARC-TH)[San Jose State University Research Foundation Inc]

Hi ETM Tabletop Participant,

Below is the link to our **Round 2 Questionnaire**. Please wait until we've completed the Round 2 discussion before starting this questionnaire.

Follow this link to the Questionnaire:
Round 2 Questionnaire

Or copy and paste the URL below into your internet browser:
https://sjsu.qualtrics.com/jfe/form/SV_5cDnNAaRvsIK6xg?
Q_DL=XYxXDTCem13HBs5_5cDnNAaRvsIK6xg_CGC_PhH0Zd6GL7EUT0h&Q_CHL=email

In these questions, we are looking for your expertise as operational experts.

In some questions, we ask for responses about *specific* vehicle types (i.e., Balloons, Airships, Slow HALE Fixed Wing).

For these questions, please provide a response for **ALL vehicle types with which you are familiar and have experience**. Leave responses for other vehicle types blank.

Questions Prior to Training for Round 3

~15 Minute Break

Day 2 Agenda Overview: Round 3

Day 2: January 11, 2022 (9am – 1pm PDT)		
Round 2: Strategic Conflict Detection	**~2 hours**	
- Welcome Back and Training/Familiarization	30 min	Connie
- Discussion	75 min	Paul
▪ OI Intersect		
▪ OI Intersect Triggers		
▪ Conflict Probability/Likelihood		
▪ Assess Parameters and Decision Points		
- Online Questionnaire	10 min	
Break	15 min	
Round 3: Cooperative Operating Practices (COPs) for Strategic Deconfliction	**~2 hours**	
- Training/Familiarization	15 min	Connie
- Discussion	70 min	Mark
▪ NASA and AIA Draft COPs		
▪ General Assumptions for COPs		
▪ Iterative Walkthrough of 3 Types of COPs		
▪ COPs Process/Agreement/Actions/Formats		
- Online Questionnaire	10 min	
Tabletop Wrap-Up	15 min	

Tabletop Training: Round 3
140~ Cooperative Operating Practices (COPs)

COPs for Strategic 'De-confliction'

100
Operator develops Operation Plan

140
Operators coordinate to address the conflict notification

110
Operator submits initial or an updated Operation Plan with Operational Intent (OI) to the ETM system

120
ETM system accepts/ rejects Operation Plan

NO

YES

130
ETM system informs of any OI intersection

YES

NO
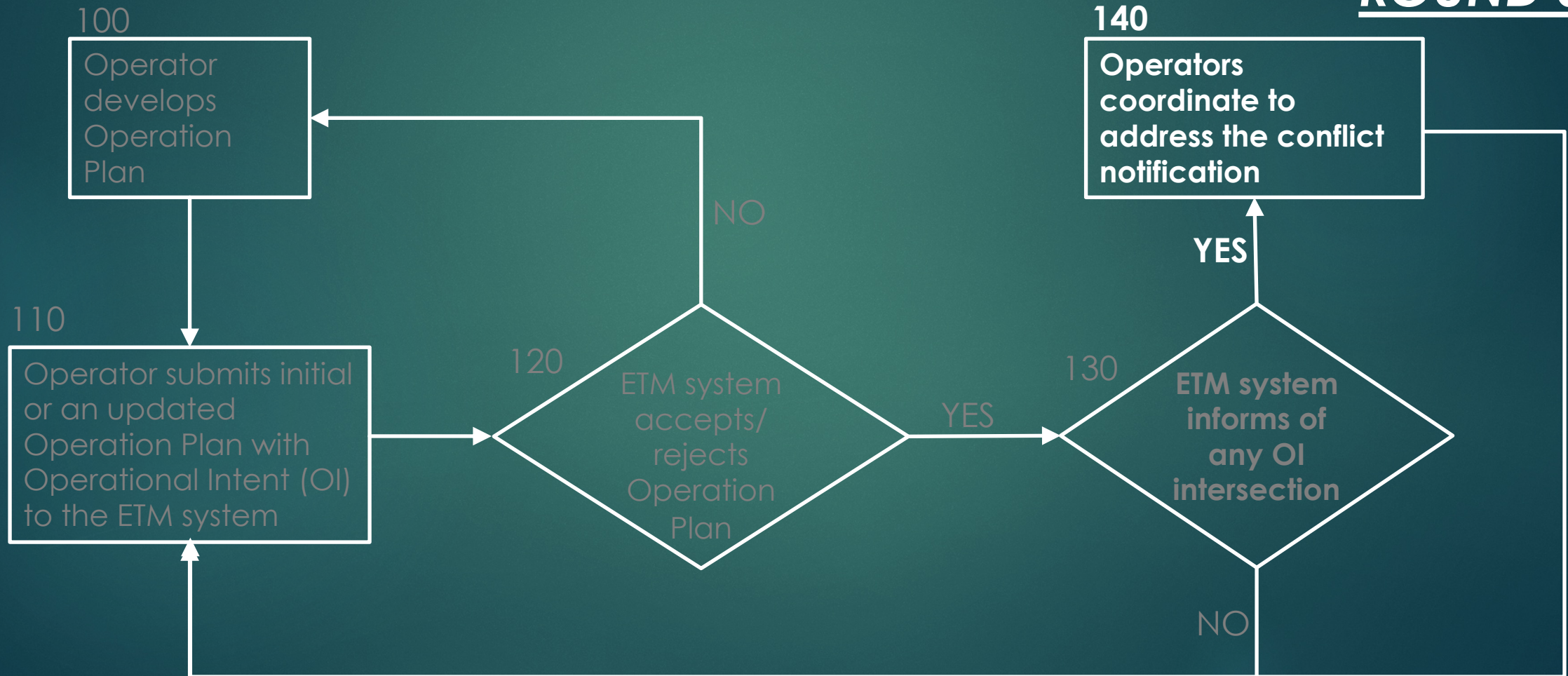
Cooperative Operating Practices (COPS) Collaborative Resolution *AIA Paper (April 2022)

*AIA First Stage: Free resolution or negotiation
*AIA Second Stage: Standard resolution and tie-breaker protocol
*AIA Third Stage: Fallback emergency rules

Cooperative Operating Practices (COPS) Round 3 NASA & *AIA Draft COPS

▶ *AIA First Stage: Free resolution or negotiation (Hybrid with Second Stage: Standard Protocol/Tie-breaker)
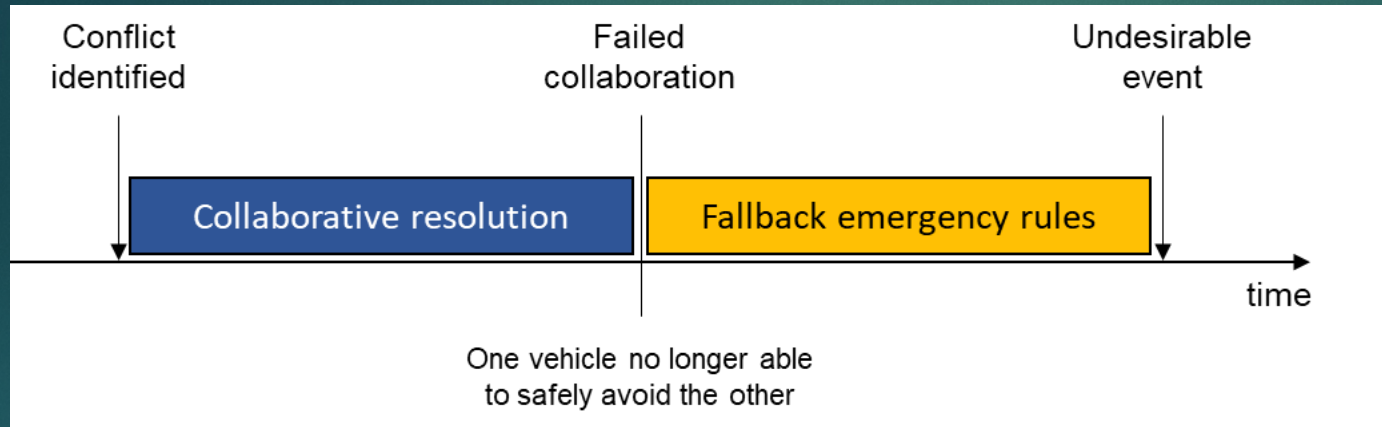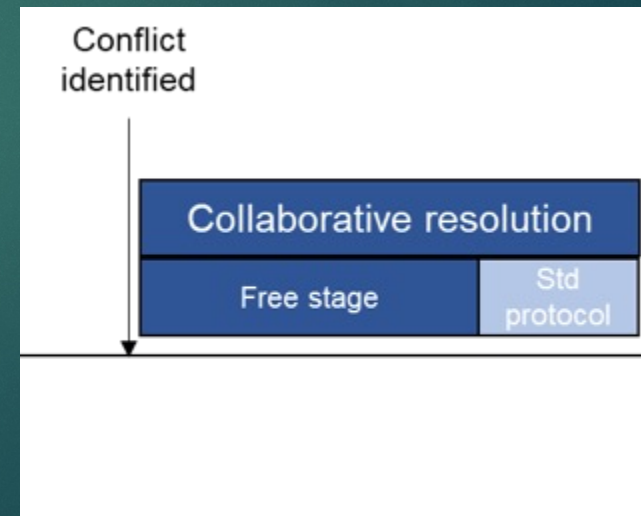
▶ NASA COP_DYNAMIC_AGREEMENT - De-confliction through dynamically generated/negotiated agreement

▶ NASA COP_PREDEFINED_AGREEMENT - De-confliction through pre-defined agreement

   ▶ Wait-and-Watch Method

   ▶ Most Performant Operator Moves

   ▶ Both Operators Move

   ▶ Vehicle - Vehicle or Company - Company

   ▶ Other? (Market driven or 50/50 random choice option-standard protocol ideas..)

▶ NASA COP_FIRST_RESERVED - De-confliction through first-reserved-first-served principle (baseline)

'In the stratosphere, negotiation is key'

Process Flow of COPS for strategic de-confliction Simple

- ▶ Submit an OP/OI

- ▶ OI Intersect Detected? (YES)

  - ▶ Ad Hoc, Pick up the phone and negotiate

  - ▶ Was negotiation successful? (YES)

    - ▶ Perform Agreed Solution

    - ▶ Update OP/OI

Process Flow of COPS for strategic de-confliction Simple ad-hoc turned into pre-agreed negotiations

▶ Submit an OP/OI

▶ OI Intersect Detected? (YES)

  ▶ Was negotiation successful or do you prefer to go straight to Pre-agreed resolution method (Yes Pre-agreed Resolution)

    ▶ Wait-and-Watch

    ▶ More Performant Operator Moves

    ▶ Combination of both operator's move

    ▶ Vehicle - Vehicle or Company – Company Agreements

    ▶ Shrink OI for x-amount of time…

    ▶ Stop and Hover/Loiter for x-amount of time

    ▶ Other? Standard protocol or Tie breaker resolution enacted

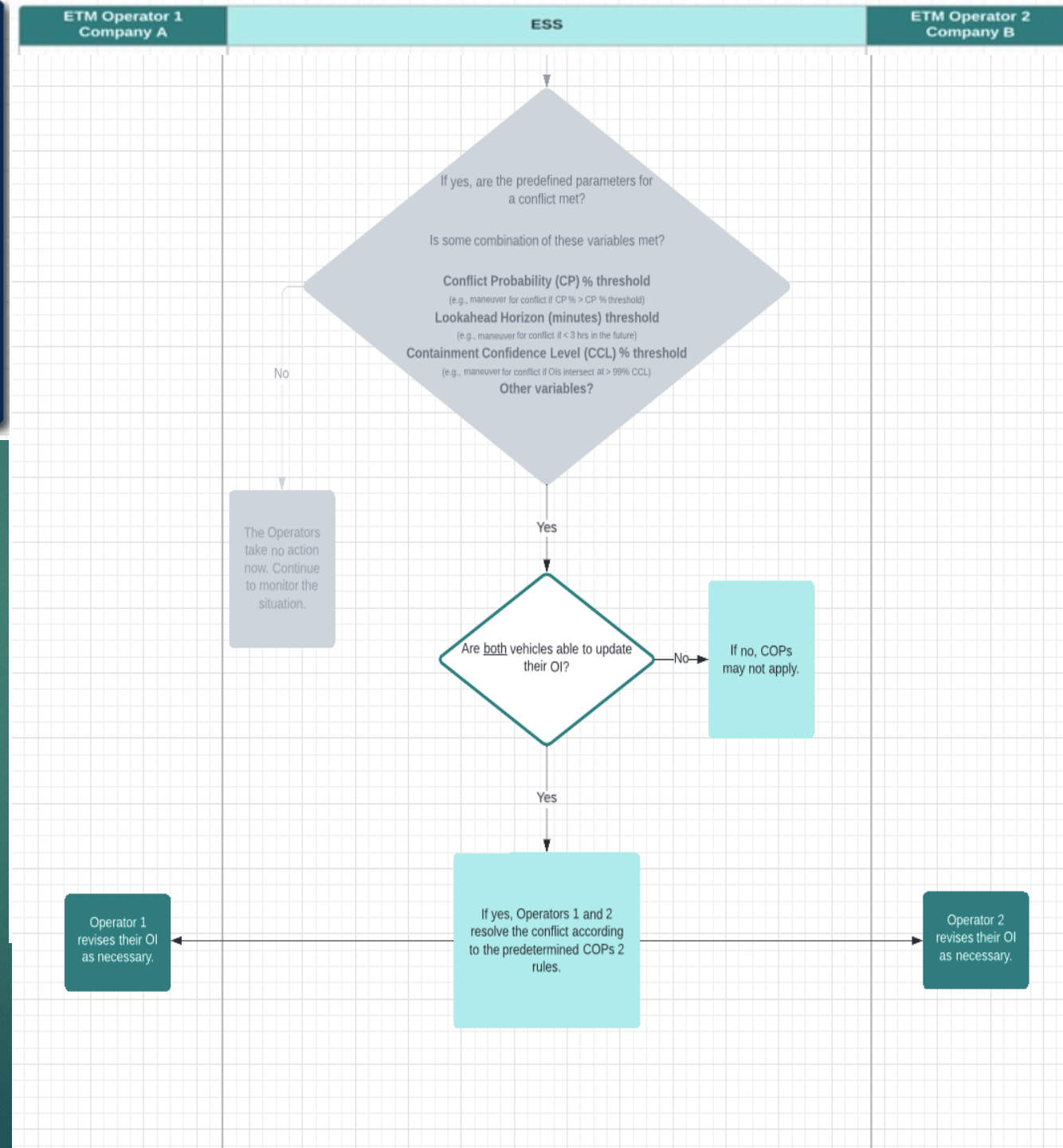   ▶ Market driven or

      ▶ 50/50 random choice option-

Round 3

Operator 1 submits an updated Operation Plan due to changes in the mission, difficulty in meeting the current OI, or because they have reached the end of the OI rolling window time horizon.

The ESS detects an intersection with another OI. The Operators resolve the intersecting OIs using COPs 2 rules.
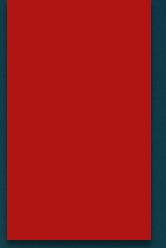
▶ Scenario for Round 3 (100/110/120/130/140)

  ▶ Query the system for other operations

  ▶ Build OP (actively work to make conflict free?)

  ▶ Submit OP/OI

  ▶ **Accepted _with_ Conflict**

    ▶ **Strategic Conflict 'Detection' OI Intersect**

    ▶ **Probability/Likelihood of actual vehicle conflict**

    ▶ **Assess Situation**

    ▶ **Decision Points (wait-and-see)**

  ▶ **COPs for strategic 'de-confliction'**

ETM Operator 1 Company A | ESS | ETM Operator 2 Company B

If yes, are the predefined parameters for a conflict met?

Is some combination of these variables met?

Conflict Probability (CP) % threshold
(e.g., maneuver for conflict if CP % > CP % threshold)
Lookahead Horizon (minutes) threshold
(e.g., maneuver for conflict if < 3 hrs in the future)
Containment Confidence Level (CCL) % threshold
(e.g., maneuver for conflict if OIs intersect at > 99% CCL)
Other variables?

No — The Operators take no action now. Continue to monitor the situation.

Yes — Are both vehicles able to update their OI? — No → If no, COPs may not apply.

Yes — If yes, Operators 1 and 2 resolve the conflict according to the predetermined COPs 2 rules.

Operator 1 revises their OI as necessary.

Operator 2 revises their OI as necessary.

Detailed Discussion Questions Round 3

Mark Evans

Round 3: Cooperative Operating Practices (COPs)
for Strategic Deconfliction

Primary Focus

- COPs ESS Coordination

- COPs Initiation Process

- COPs Maneuvers

- COPs Procedures or Actions

- Format of the COPs Agreement

Coordination with ESS

– If either, or both, operators initiate a strategic deconfliction maneuver under COPs, should there be a specific mechanism to let the ESS know or would the updated OI be adequate?

– Does the ESS need to notify the other operator that an OI update is taking place?

– Is there a need for the ESS to notify operators once the OI update results in strategic deconfliction?

We have outlined a process wherein an operator decides that an OI volume intersection should be resolved based on likelihood, time to conflict, and other factors.

If an OI intersection needs to be resolved, one or both vehicle operators look to see if there exists a specific, pre-coordinated COPs procedure for the two companies, two vehicle types, etc.

The operator(s) start the COPs negotiation process, if one exists.

- Does this process sound reasonable? Are there other ideas about how to do this?

- Should COPS be set up between two companies? Between each vehicle type pair (e.g., balloon/balloon, balloon/HALE, etc.)? Other options?

- What would you default to if there is no pre-coordinated COPs agreement for the vehicle pair?

Types of COPs Maneuvers

- Earlier work discussed possible strategic deconfliction maneuvers, for balloons: Holding altitude, tightening uncertainty bubble, or climbing/descending. Do you agree? Are there any other deconfliction maneuvers for Balloons? Can you provide any more detail on how this would happen?

- As possible deconfliction maneuvers, HALE FW can change loiter patterns, tighten/loosen circle patterns, change climb/descent rates, or change paths/routes. Do you agree? Are there any other deconfliction maneuvers for HALE FW vehicles? More details, if any.

- What are the available deconfliction maneuvers for Airships? Details?

What types of procedures/actions would a COPs agreement include?

- Is it specific about <u>when</u> each vehicle should maneuver?

- Is it specific about the <u>exact maneuver</u> each vehicle would / could make?

  - Would one vehicle loiter while the other vehicle climbs or descends?

- Would it ask one vehicle to move in certain situations and the other one to move in other situations?

- Other ideas of what might be included?

Based on the discussion about what specific information would be included in Strategic Deconfliction COPs, do you think they should have a standardized format?

- Could these COPs be as simple as:

  - In situation 1, operator "A" updates OI for deconfliction

  - In situation 2, operator "B" updates OI for deconfliction

  - In situation 3, Both parties update their OIs for deconfliction

  - Specify about who moves where and when

- Or would you see the COPs as either more general information or more specific information?

Given a certain set of information that would be included in Strategic Deconfliction COPs, do you have any ideas of what sort of format they might take?

– Formal FAA Rules

– Letters of Agreement, with FAA approval

– Memorandum of Understanding between parties

– Other ideas (e.g., automation-supported solutions)

Backup Slides

Should we ask about 3rd party arbitrators needed for other vehicle types?

- Available maneuvers within COPs
  - Balloons
    - Hold altitude to tighten the uncertainty bubble
    - Climb or Descend to resolve strategic (and tactical) conflict
  - HALE FW
    - Change loiter patterns (e.g. circle, S pattern, etc.)
    - Tighten/loosen circle radius
    - Change climb / descent rates
  - Commercial SST (not included in our Tabletop)
    - Wants to participate in CA and COPs
    - Might not be able to negotiate effectively due to vast differences in maneuverability (not actually stated but inferred from the slides)
    - Discussed available maneuver options such as letting algorithm or third-party arbitrators deciding who to move
      - Should we ask about 3rd party arbitrators needed for other vehicle types?

- Assumption of good citizenship during COPs process
  - Operators must demonstrate a willingness to collaborate, as a result there must be rules on gamesmanship
- Performance may determine what vehicle interactions are allowed
  - The cooperative community may have to consider minimum performance requirements/limits as density of operations and/or competition for airspace increases
- COPs Enforcement
  - Enforcement established and enforced via a consortium
  - Consortium collects operational data and enforce consequences to the violators and reward good citizens

Strategic Deconfliction with COPS-2 pre-defined agreement: What types of information needs to be present in a COPs agreement?

- Vehicle-to-vehicle, company-to-company?
- Is a certain action required to initiate COPs, or does it automatically trigger?
- What is the nature of COPs?
  - Agreement for one or both operators to take the responsibility of resolving the OI deconfliction?
  - Sequence of required/preferred actions on parts of both parties?
  - Detailed rules that govern the actions for all types of scenarios?
  - How should the roles and responsibilities be distributed between the operators and codified in pre-coordinated COPs?

How does strategic OI deconfliction occur?

- Does the filing of a new OI intent and volume satisfy as an implicit coordination?
  - Should there be active notice that one or more operators will initiate new OIs?
  - Should ESS issue a message that overlap is resolved to all parties?
- Do new OIs need to be deconflicted for some future timeframe X? What are the rules?
- Would automation ever provide OI adjustment suggestions?

What are the types of actions that could be used to resolve an OI volume intersection? OI volumes could be altered spatially, or time shifted to avoid OI volume intersection in following ways:

- Change in Speed
- Change in Altitude
- Change in lateral route/intent
- Change in Mode – hovering vs. moving
- Shrinking OI volume size using following:

  - Better intent information by updating OIs as time elapses
  - Better intent information achieved by moving to a location that result in less uncertainty (e.g. less winds, stable modes, etc.)
  - Finding location or flight mode that allow better maneuverability / control of the vehicle, thereby reducing uncertainty

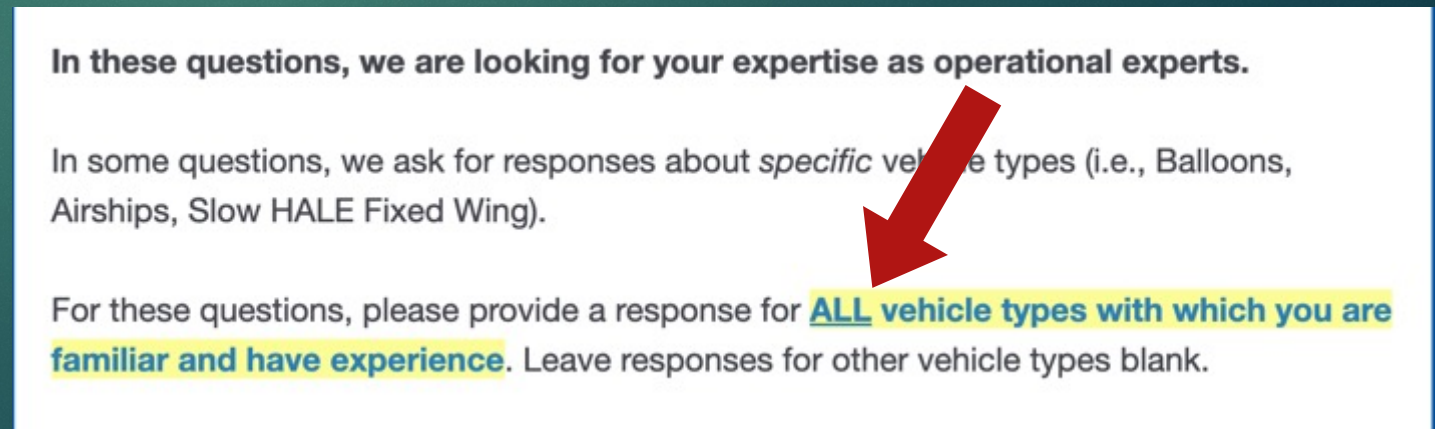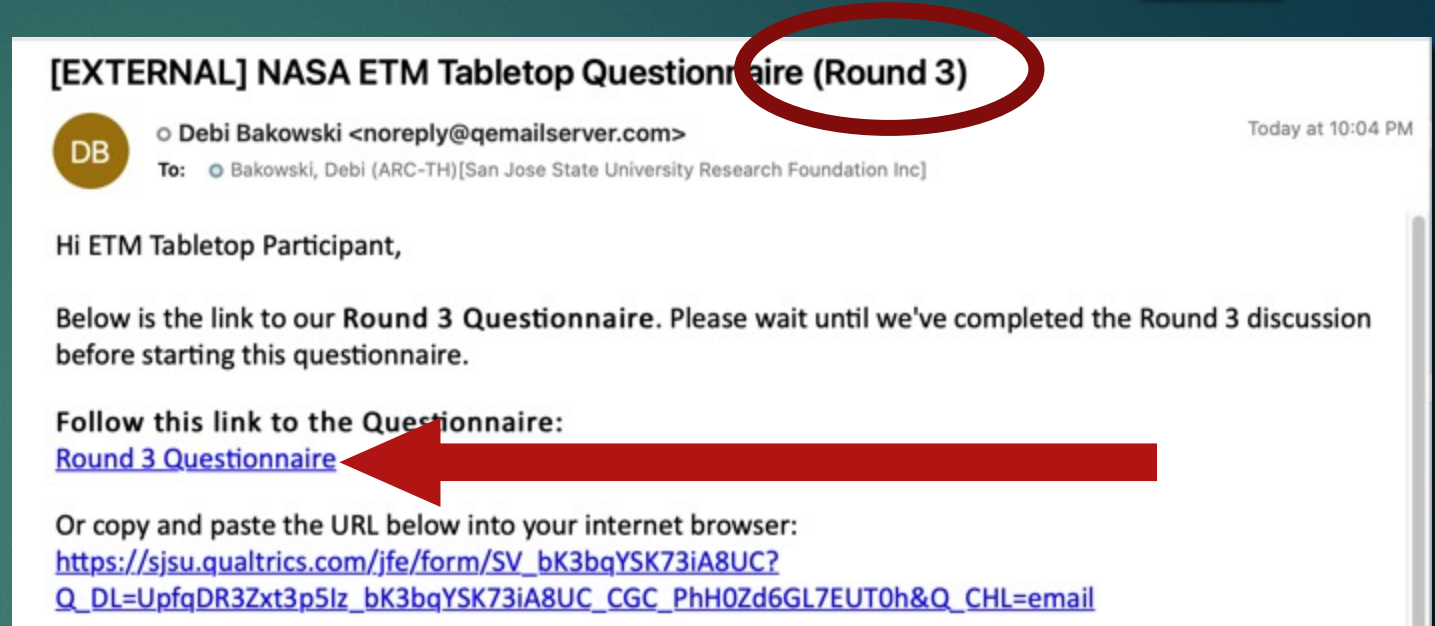## How is accountability to COPs determined?

Round 3 Questionnaire

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[EXTERNAL] NASA ETM Tabletop Questionnaire (Round 3)

○ **Debi Bakowski** <noreply@qemailserver.com>
To: ○ Bakowski, Debi (ARC-TH)[San Jose State University Research Foundation Inc]

Today at 10:04 PM

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End of Round 3 Recap

- Cooperative Operating Practices for Strategic De-Confliction
  - NASA COP2_PREDEFINED_AGREEMENT - De-confliction through pre-defined agreement
    - Wait-and-Watch Method
    - Most Performant Operator Moves
    - Both Operators Move
    - Other? (50/50 random choice option)

End of Day 2 Recap

- Strategic Conflict Detection
  - OI Intersection
  - Conflict Probability
  - Assess and Decision Points
- Strategic De-Confliction
  - COPS

End of Day 1 Recap

- ▶ Training and Lexicon for developing Operational Plan, specifically Operational Intent Volumes and needed characteristics

- ▶ Operation Plan (OP) Parameters

- ▶ Operation Intent (OI) Volume Generation Parameters
  - ▶ Containment Confidence Level (CCL)
  - ▶ Flight Info Update Rate
    - ▶ OI Segment Update Rate
    - ▶ OI Segment Duration
    - ▶ OI Segment Size Restriction
    - ▶ Total OI Time Horizon

- ▶ ETM System
  - ▶ Submit OP/OI
  - ▶ System Response